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(54) **NONLINEAR LINE OF WEAKNESS FORMED BY A PERFORATING APPARATUS**

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B32B 3/24 (2006.01)
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CPC ***B26F 1/14*** (2013.01); ***A47K 10/16*** (2013.01); *B32B 3/266* (2013.01); *Y10T 428/15* (2015.01)

(58) **Field of Classification Search**
CPC Y10T 428/15; Y10T 428/24273; Y10T 428/24298; Y10T 428/24306;
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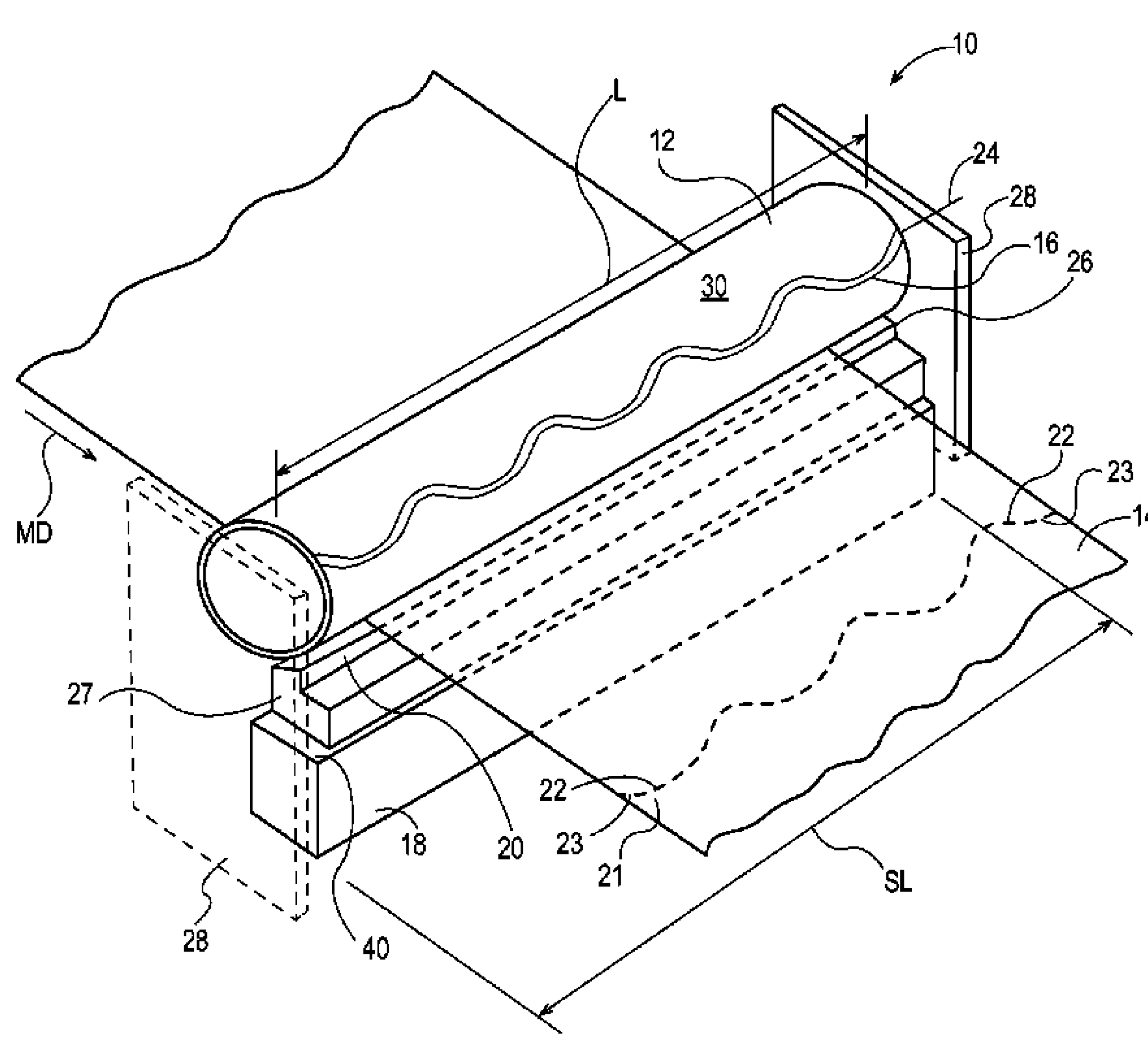
(57) **ABSTRACT**

A web includes a curvilinear line of weakness. The curvilinear line of weakness includes a plurality of perforations. Each of the plurality of perforations is separated by a bond area. Each of the plurality of perforations has a perforation length and each bond area has a non-perforation length. In one embodiment, at least two of the perforations lengths are substantially equal. In an alternate embodiment, at least two of the non-perforations lengths are substantially equal. In yet another embodiment, at least two of the non-perforations lengths are substantially unequal and at least two of the perforation lengths are substantially unequal.

7 Claims, 20 Drawing Sheets



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(58) **Field of Classification Search**
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USPC 428/43, 131, 134, 136, 137
See application file for complete search history.

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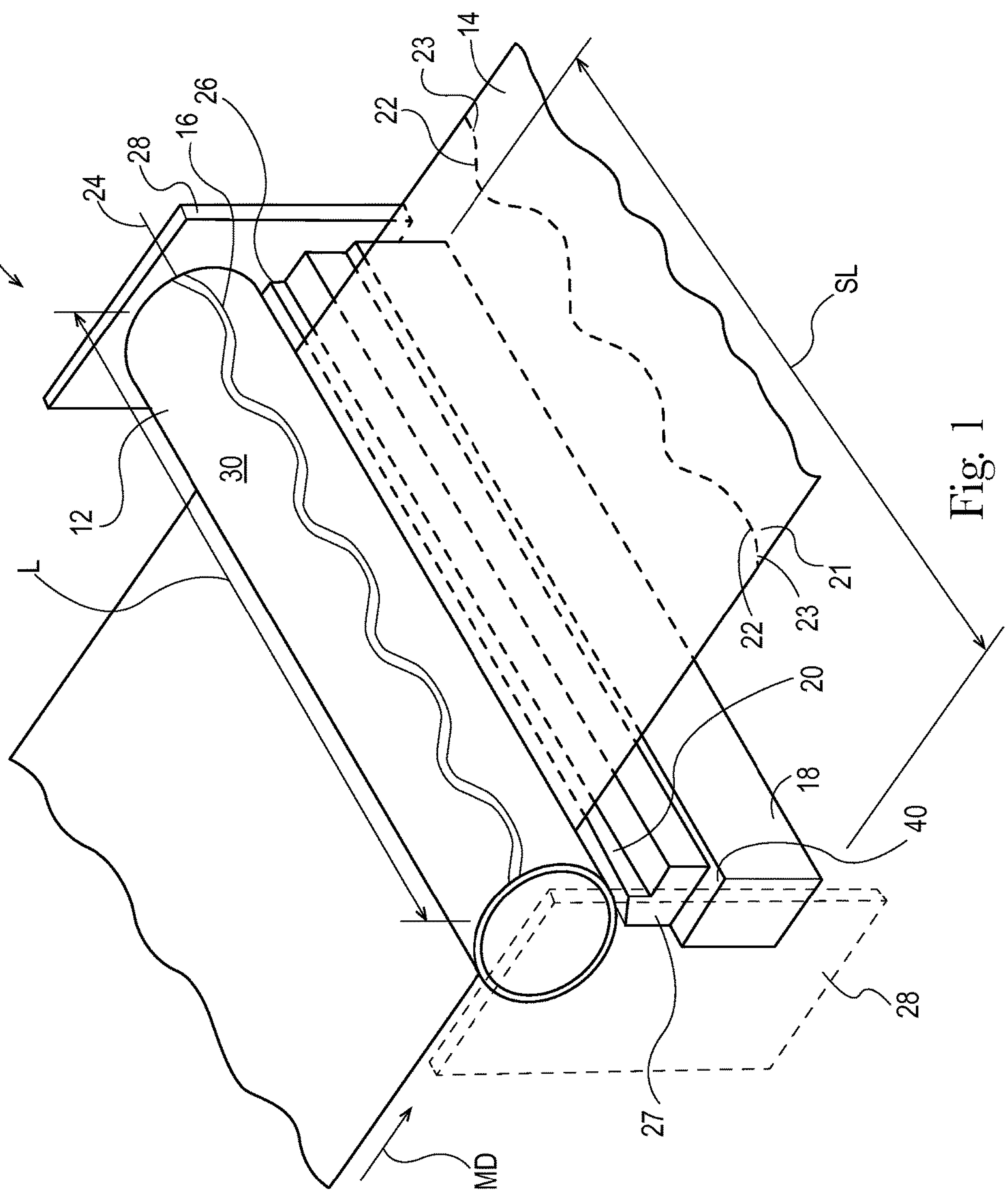

Fig. 1

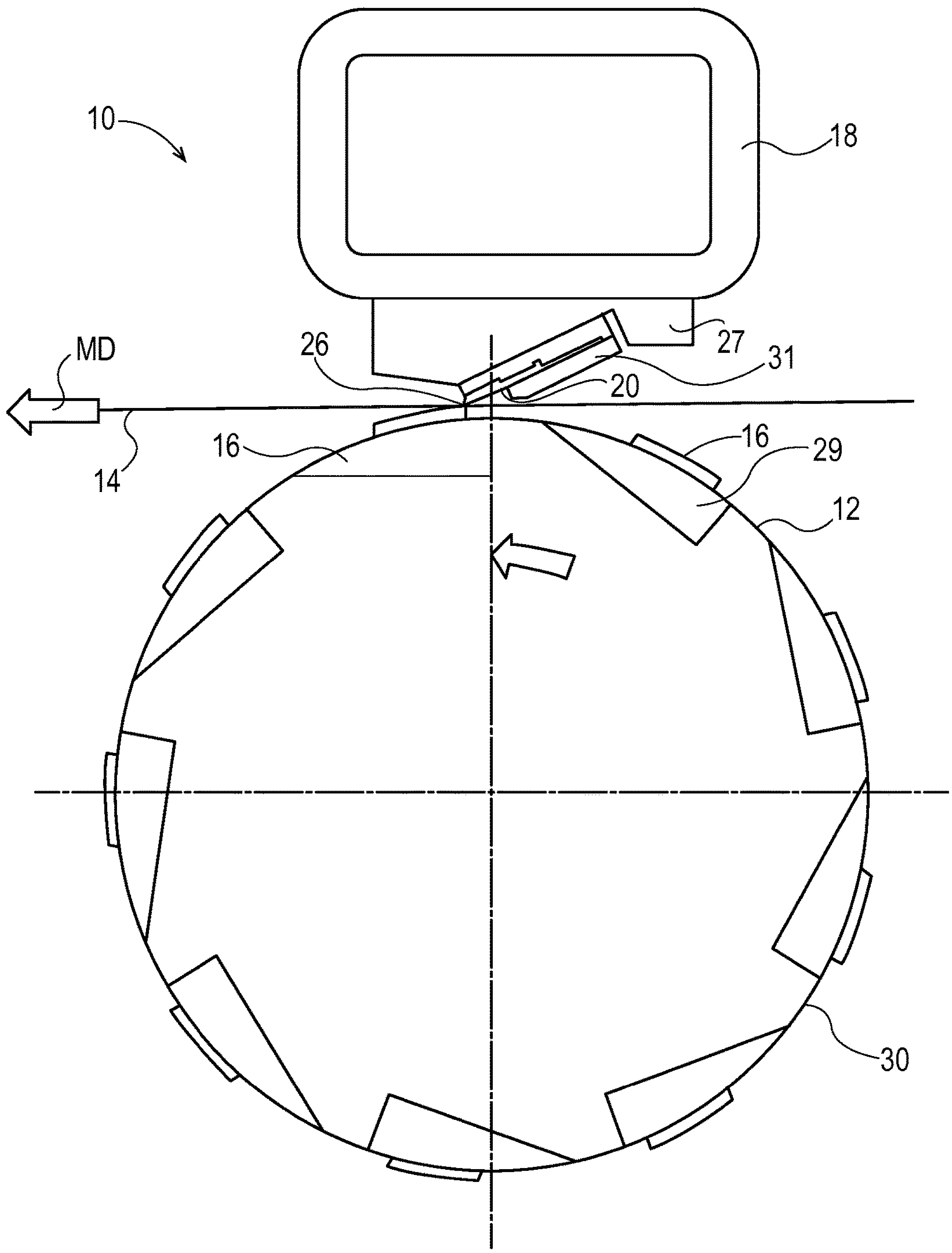

Fig. 2

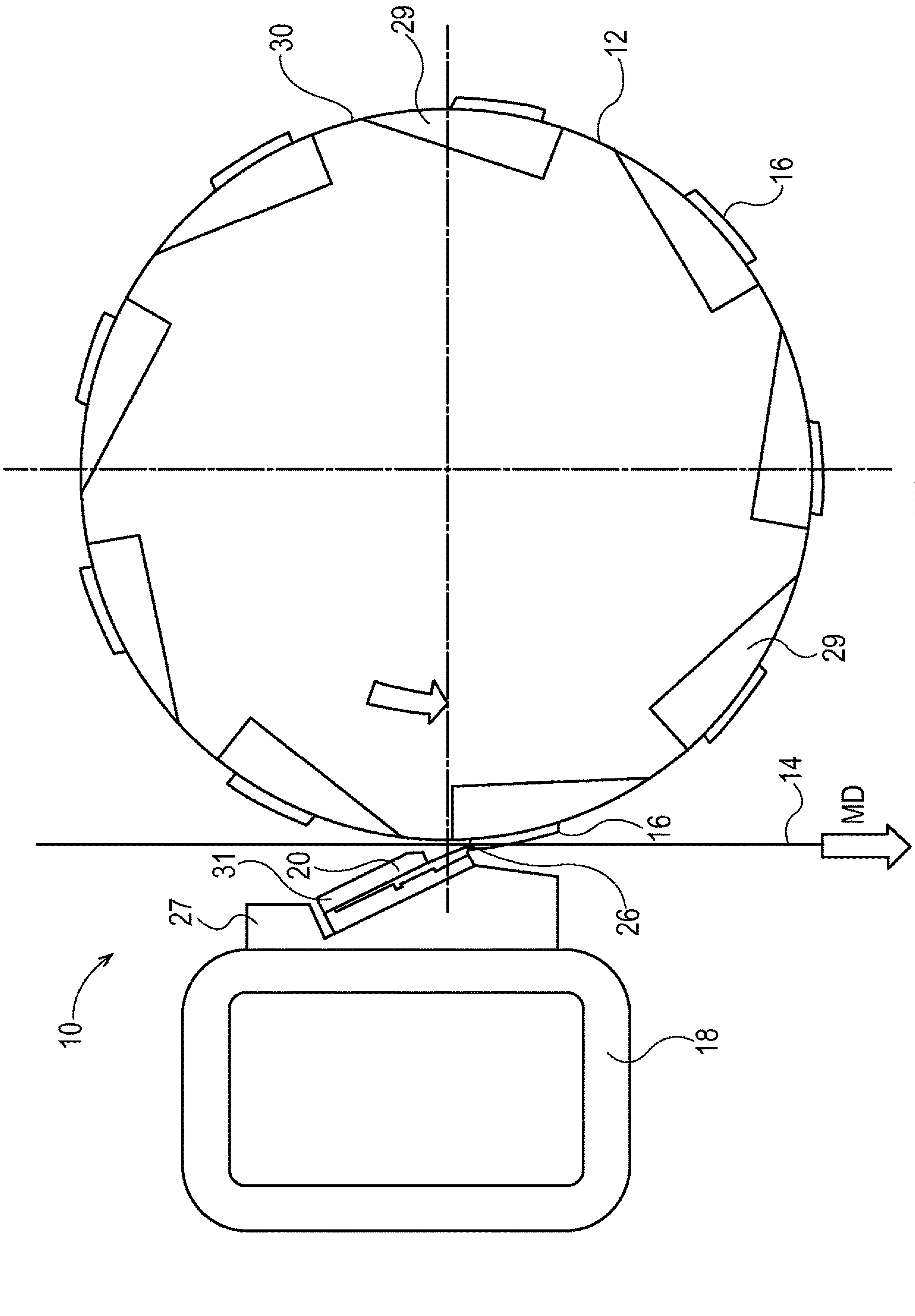

Fig. 3

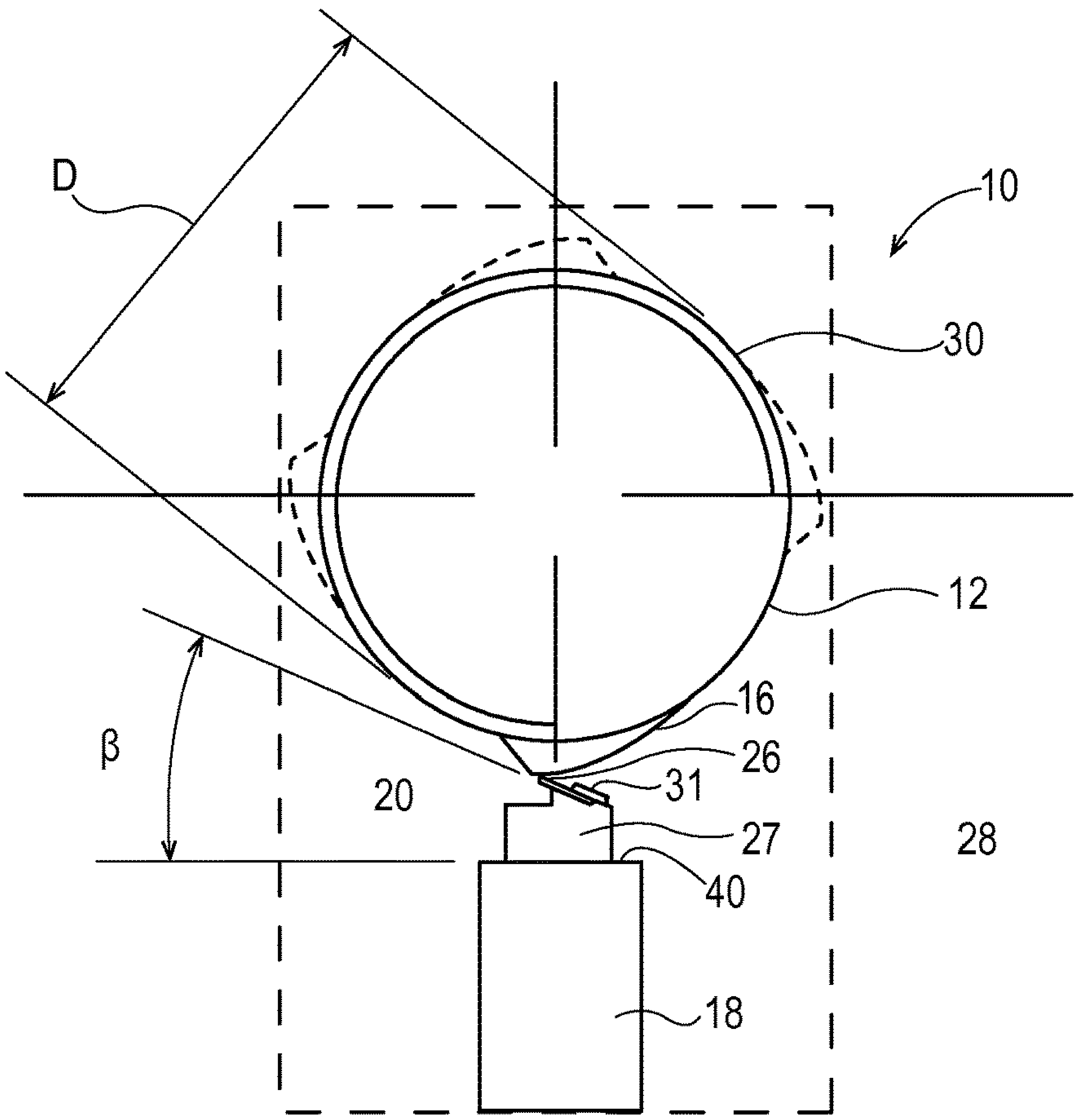

Fig. 4

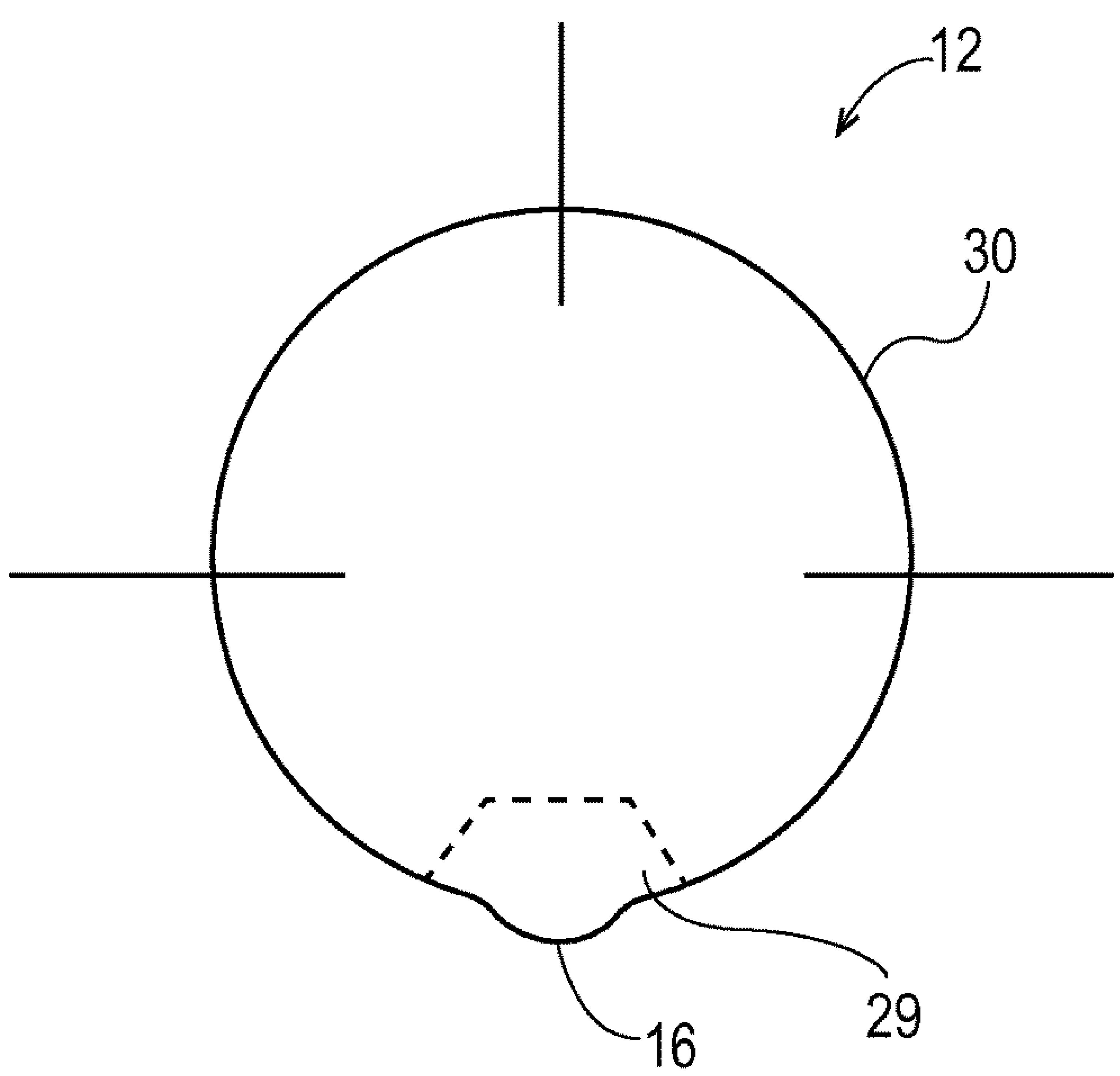

Fig. 4A

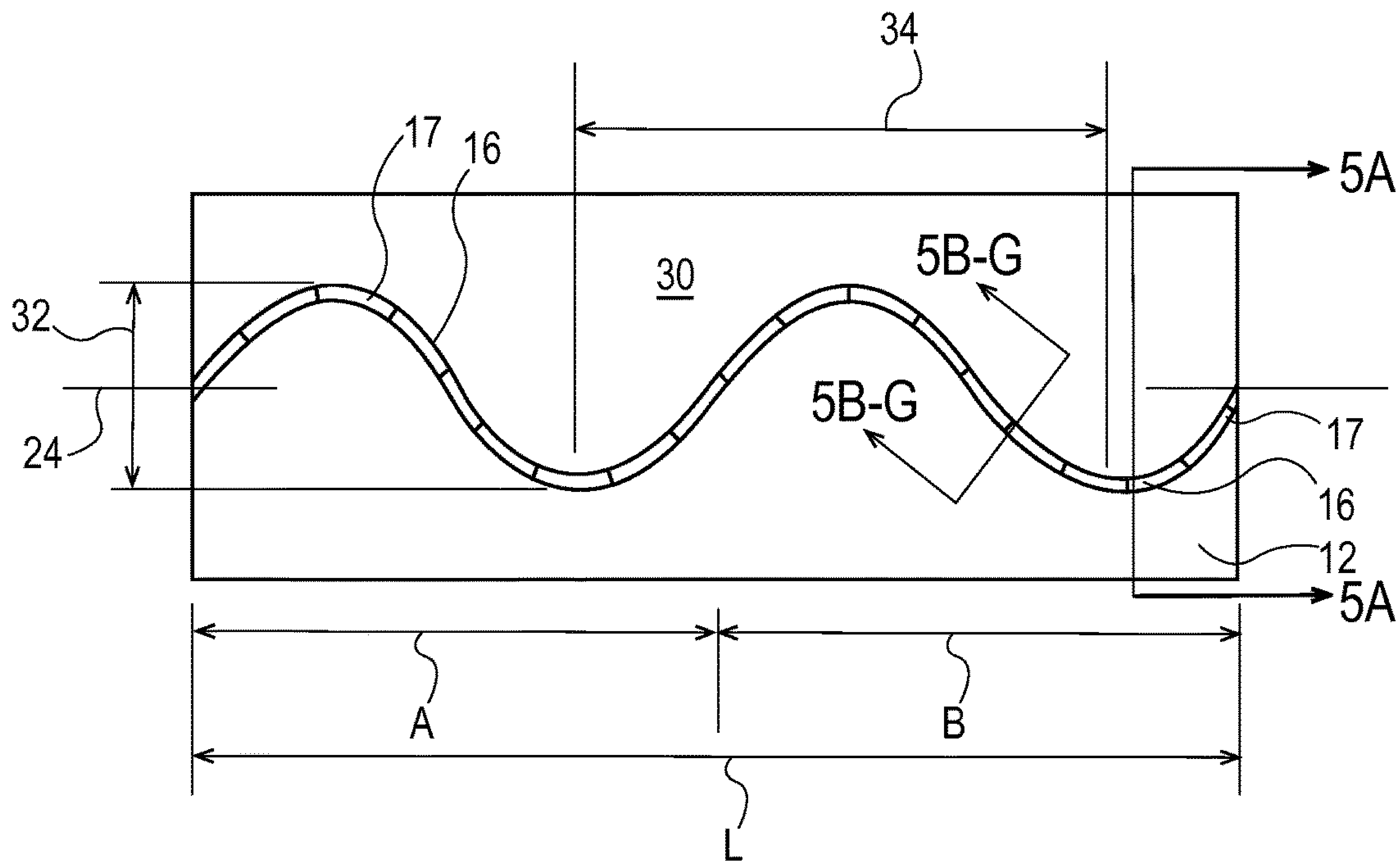

Fig. 5

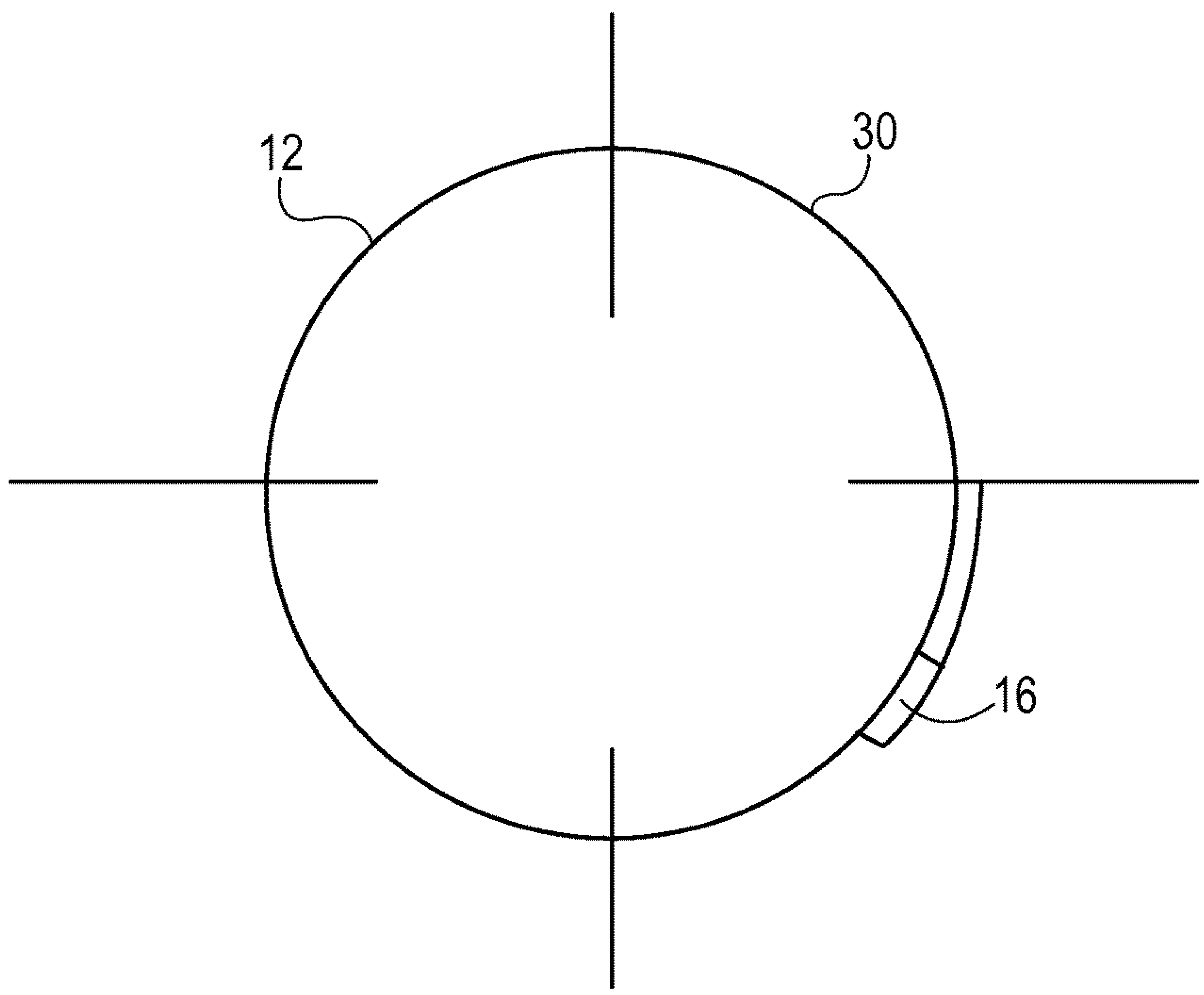

Fig. 5A

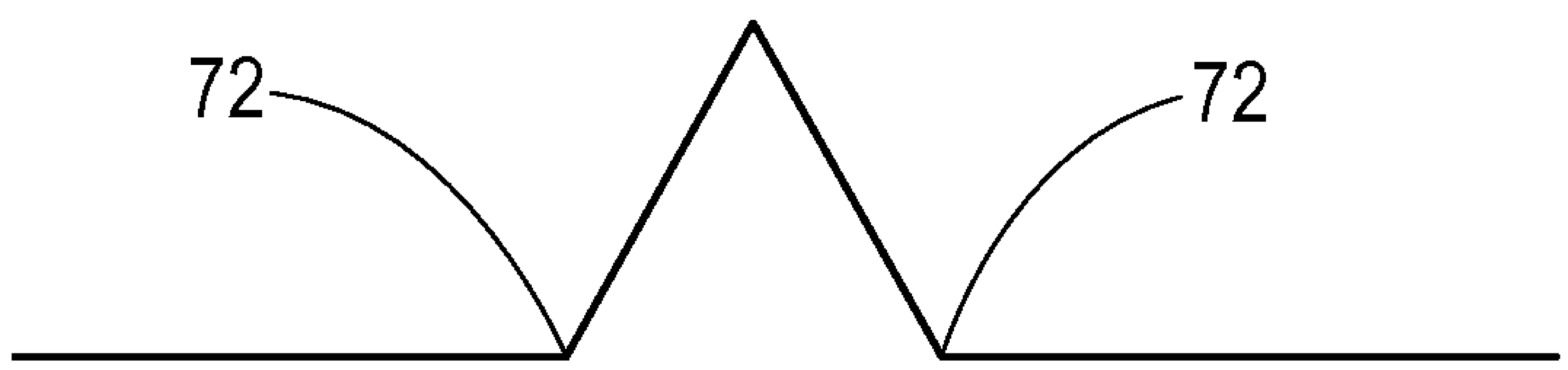

Fig. 5B

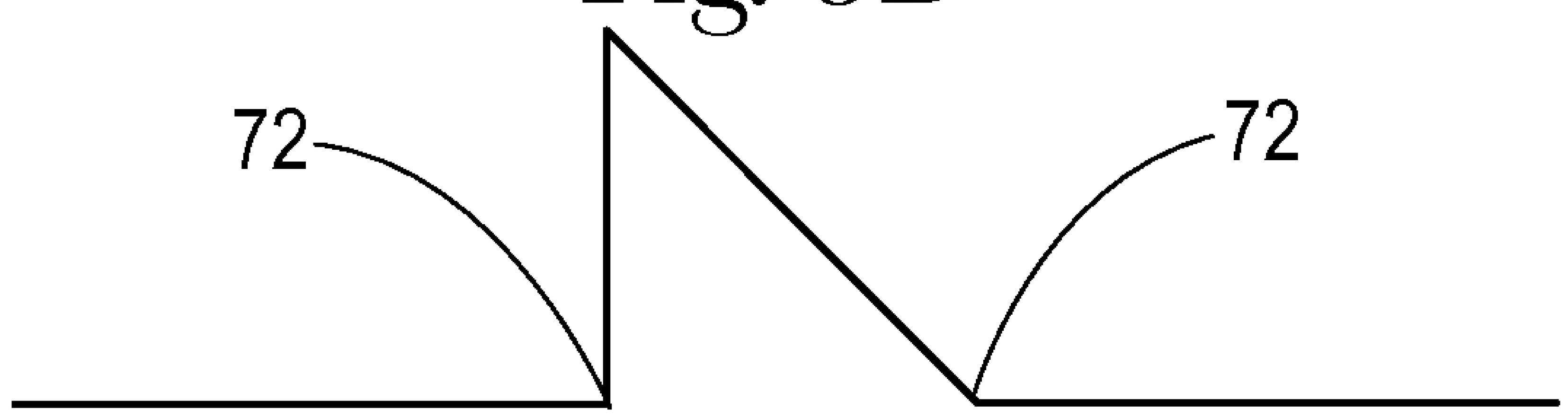

Fig. 5C

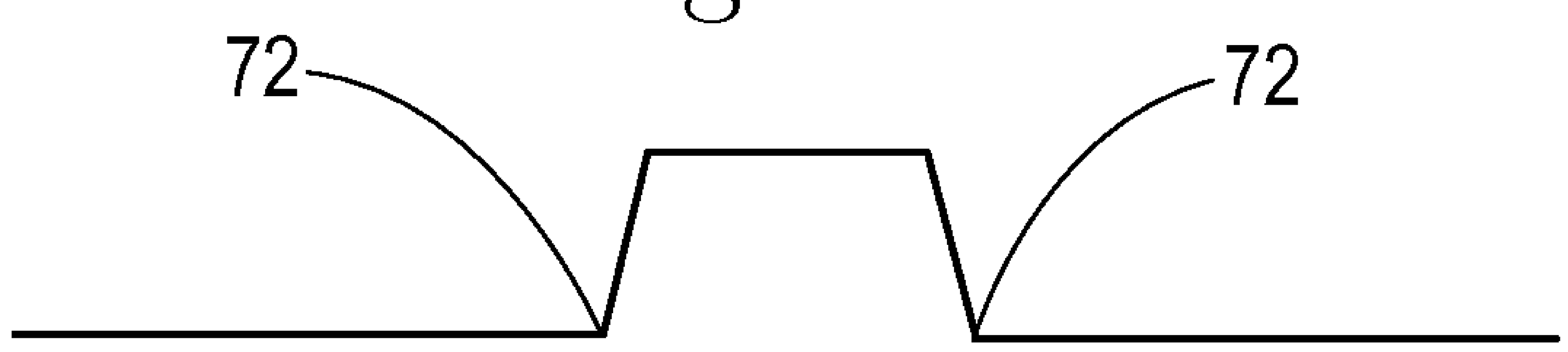

Fig. 5D

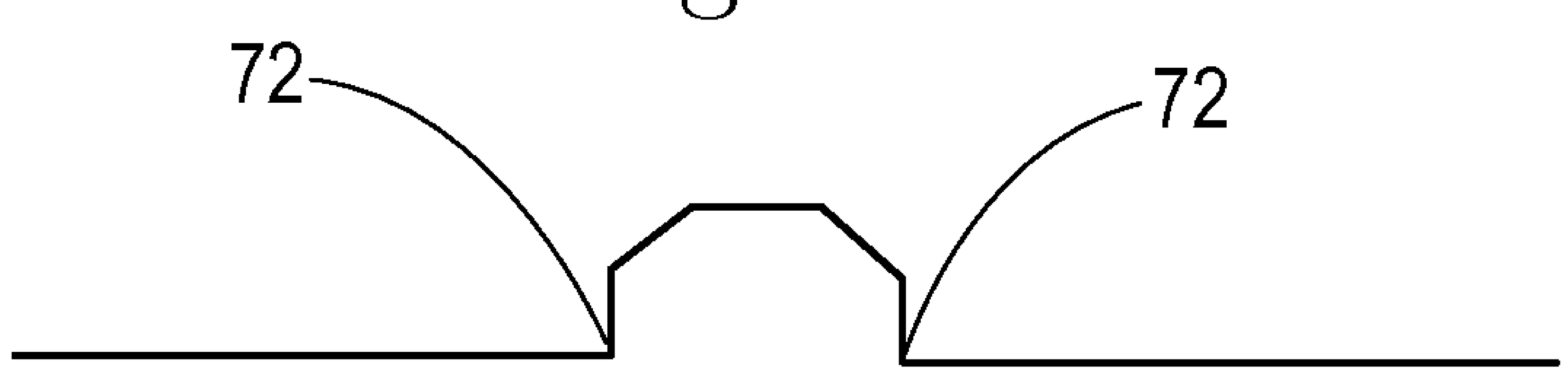

Fig. 5E

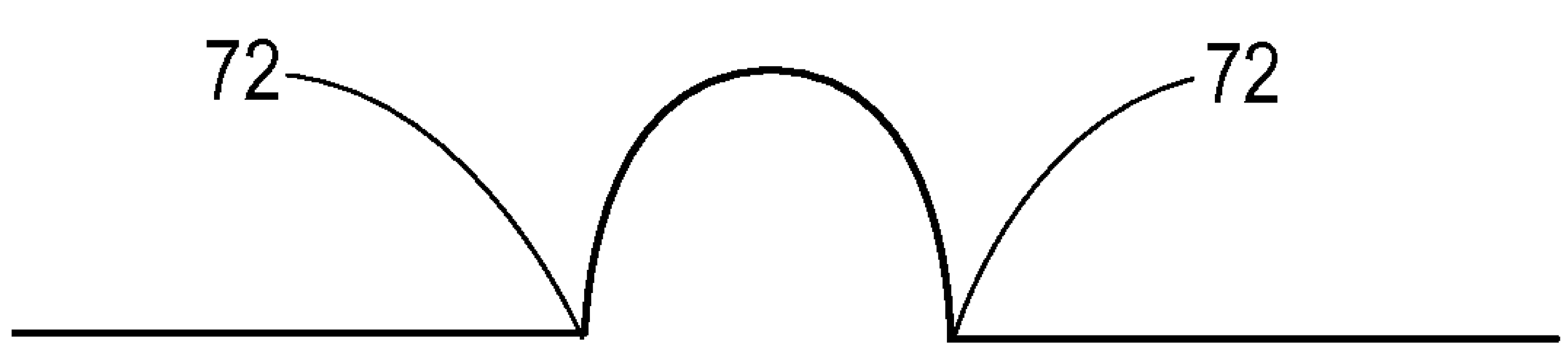

Fig. 5F

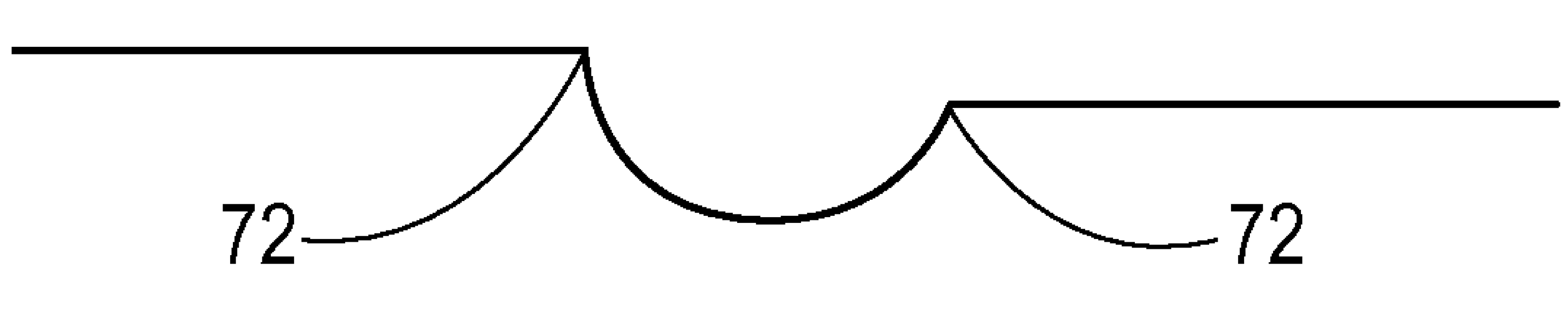

Fig. 5G

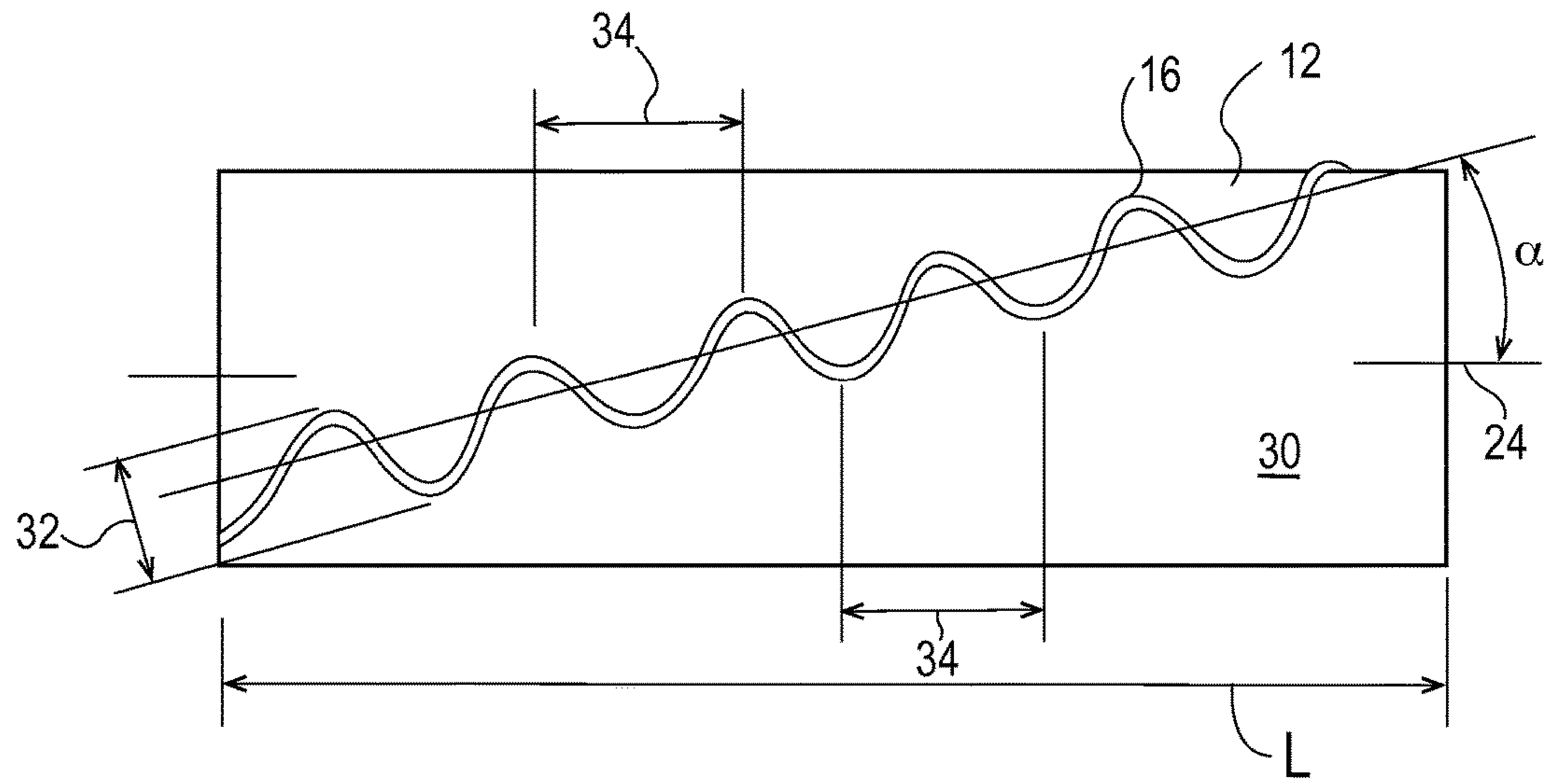

Fig. 6

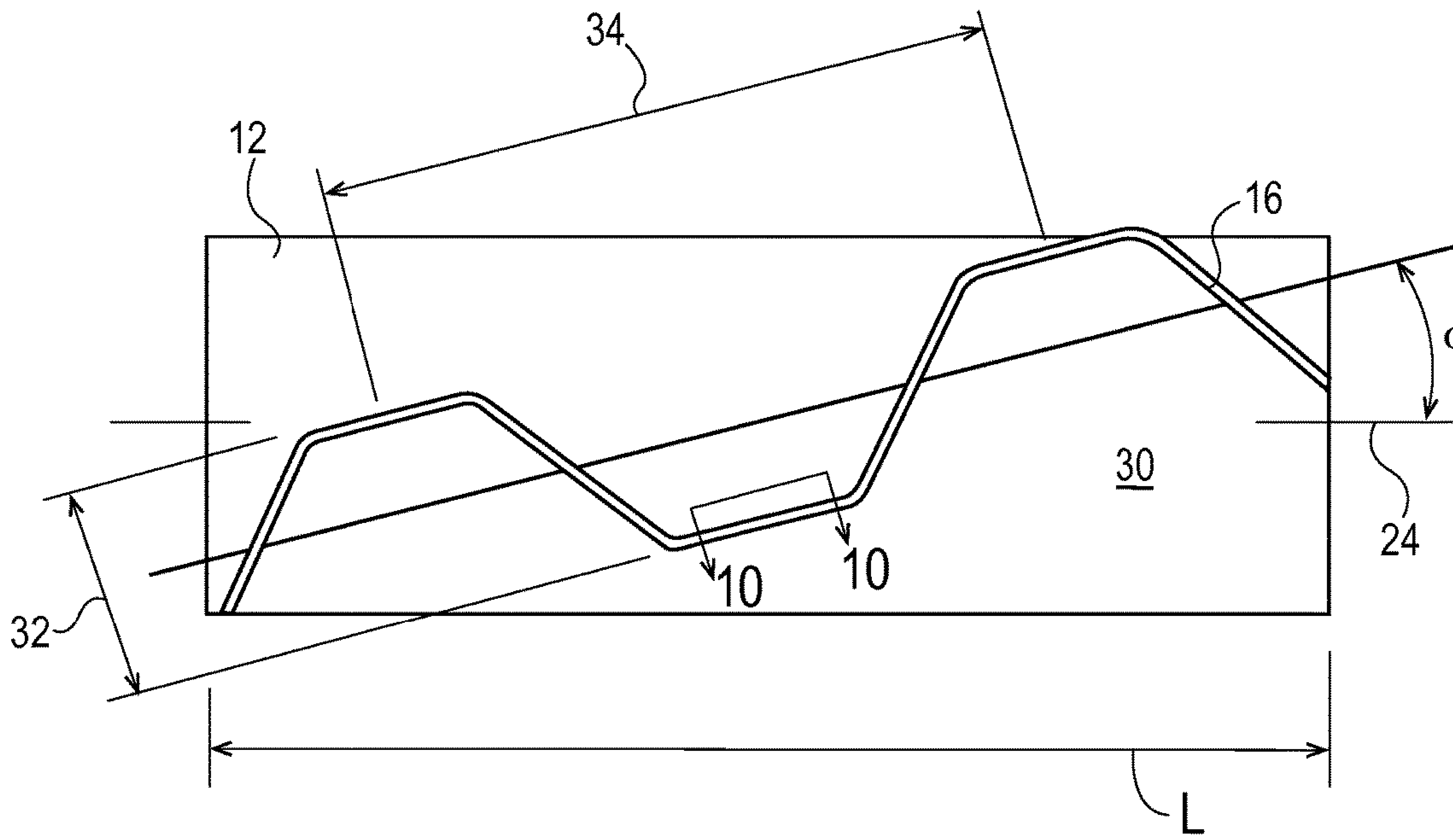

Fig. 7

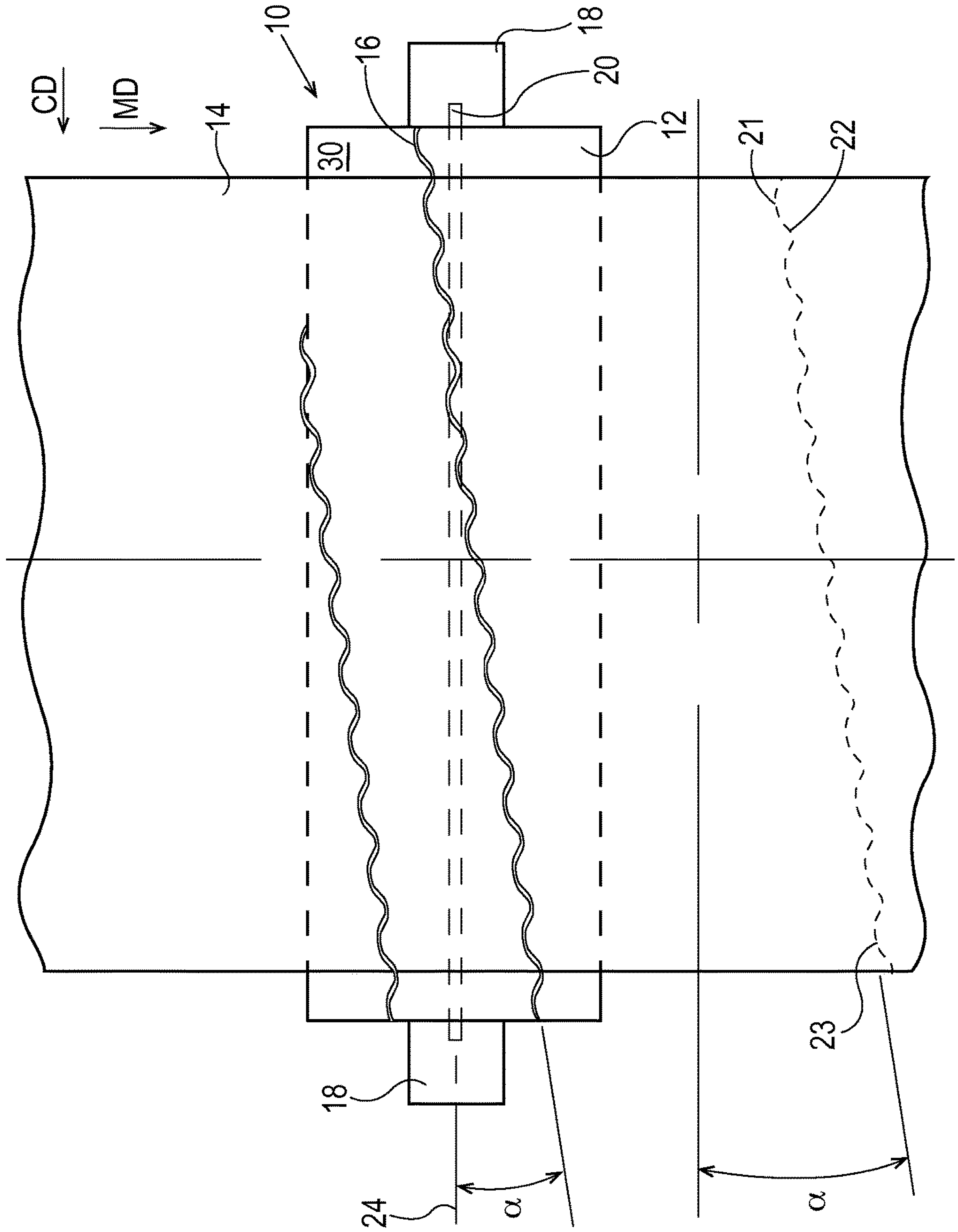

Fig. 8

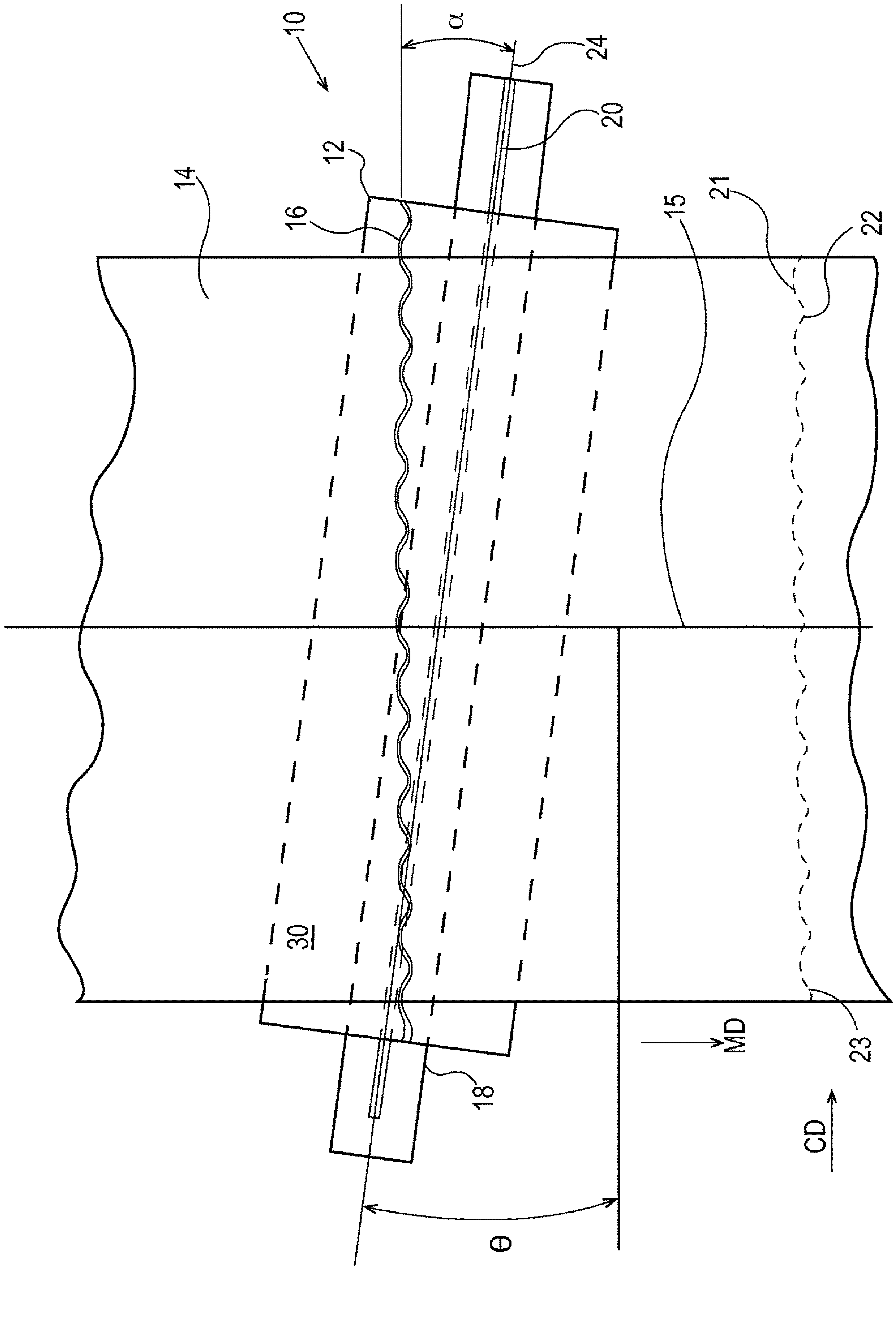

Fig. 9

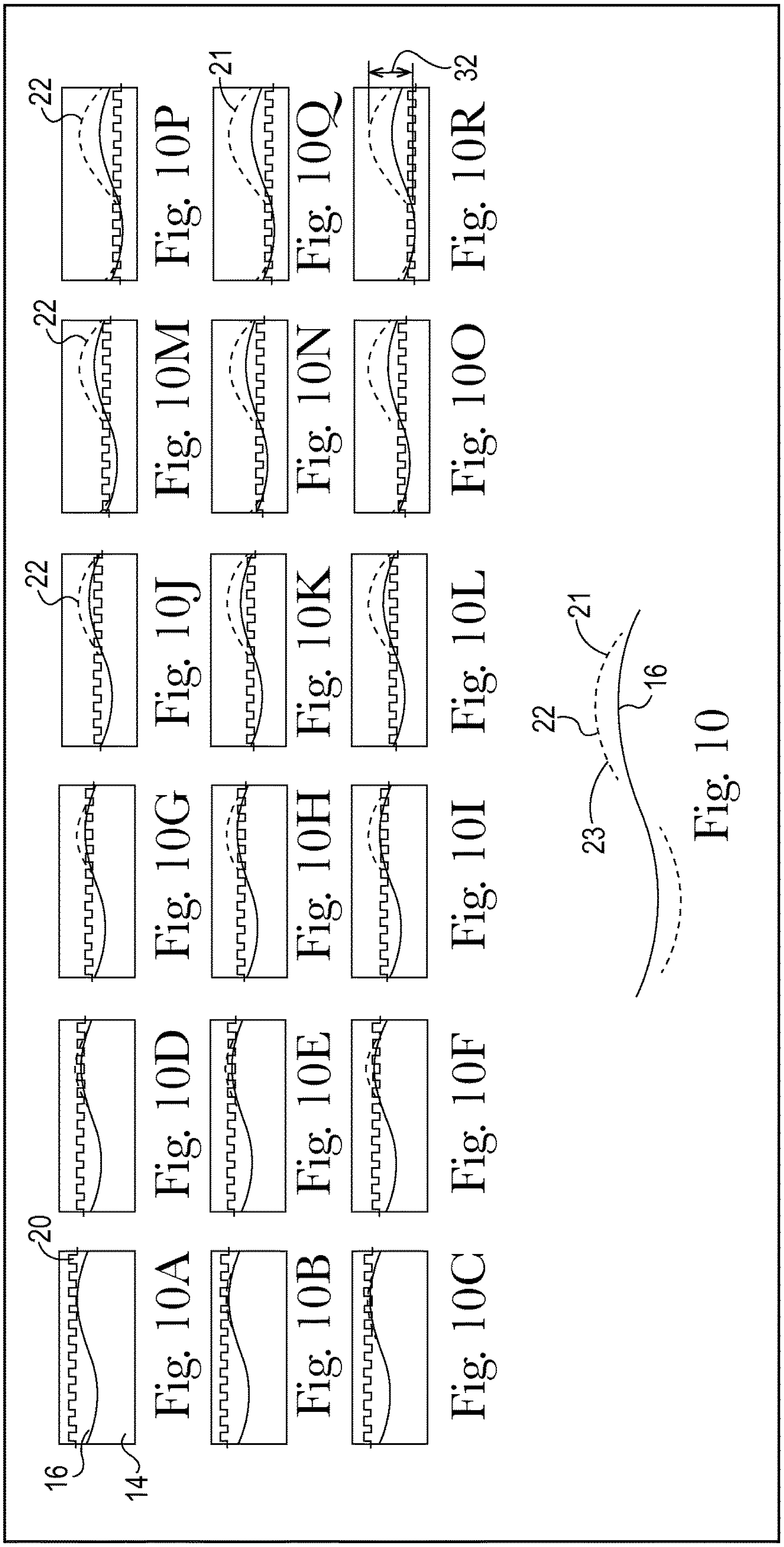

Fig. 10A Fig. 10B Fig. 10C Fig. 10D Fig. 10E Fig. 10F Fig. 10G Fig. 10H Fig. 10I Fig. 10J Fig. 10K Fig. 10L Fig. 10M Fig. 10N Fig. 10O Fig. 10P Fig. 10Q Fig. 10R

Fig. 10

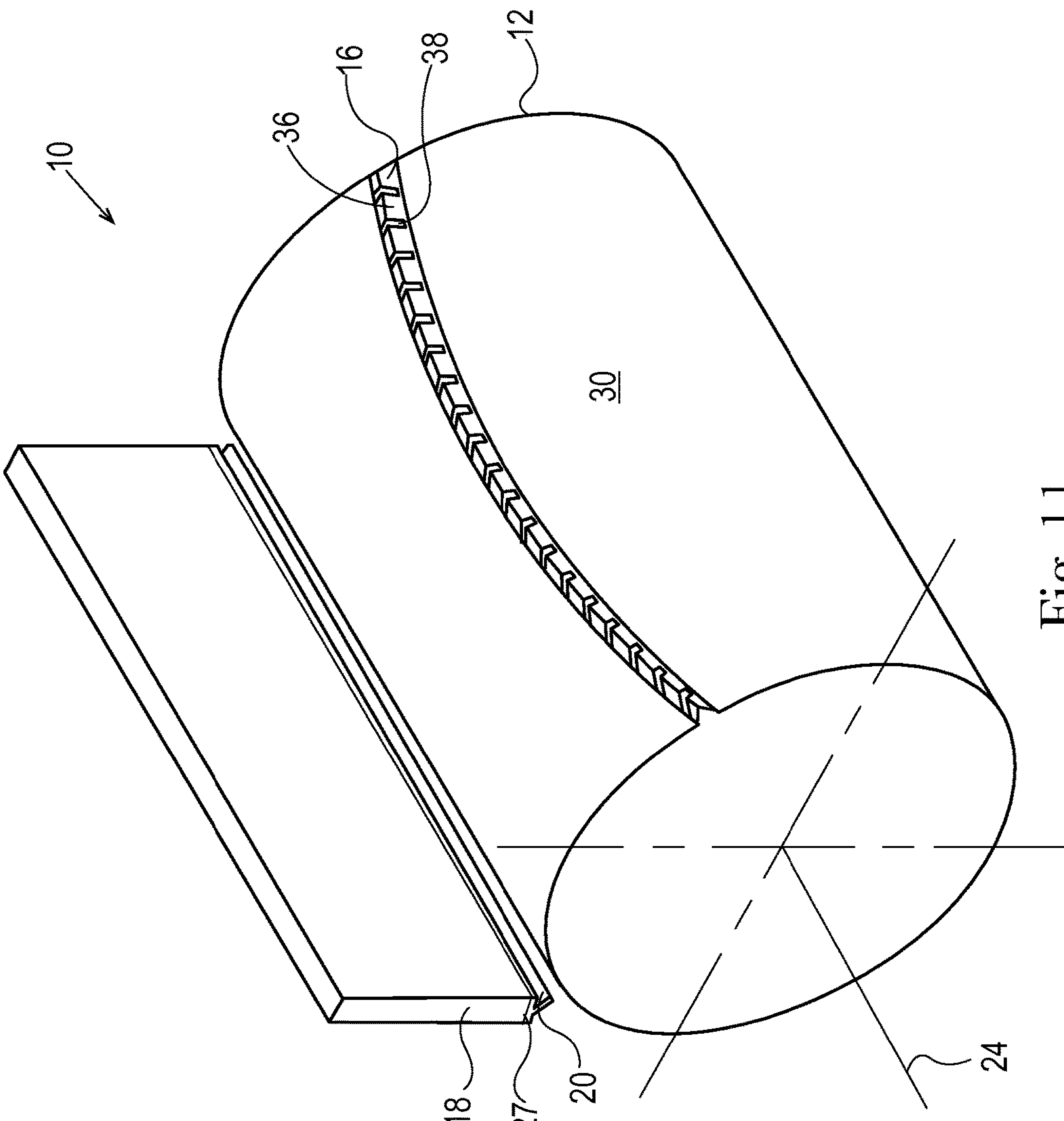

Fig. 11

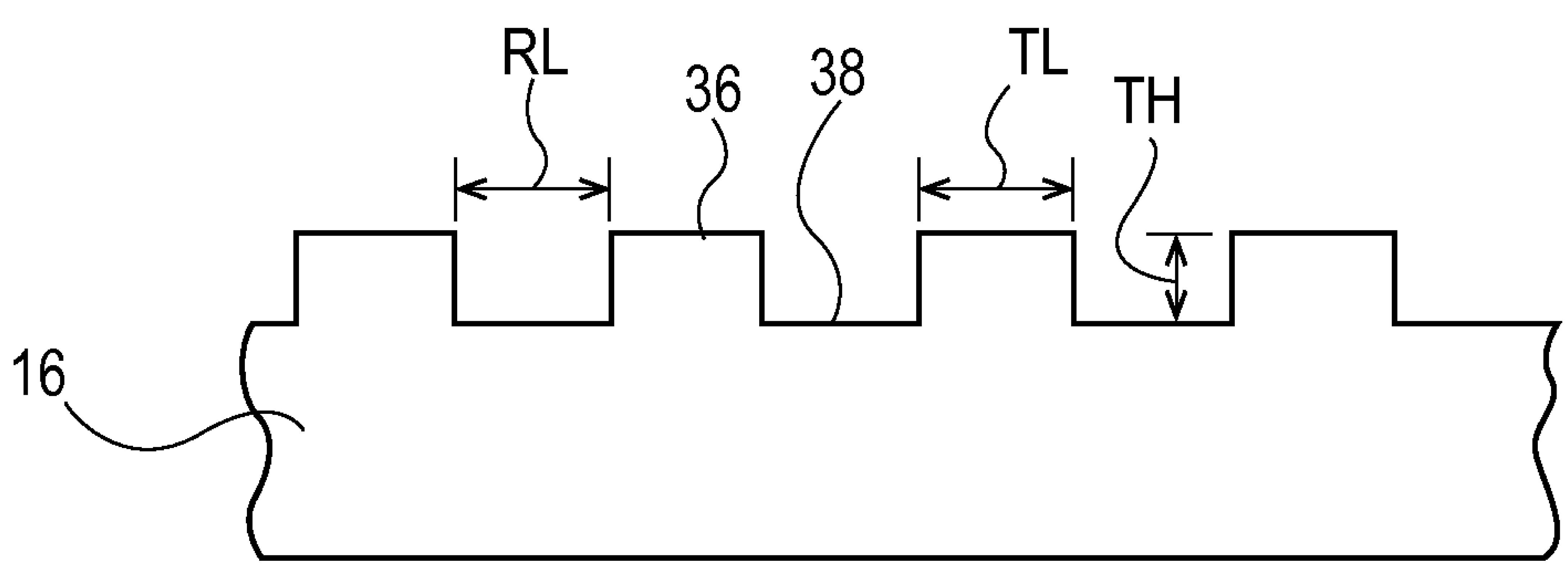

Fig. 12

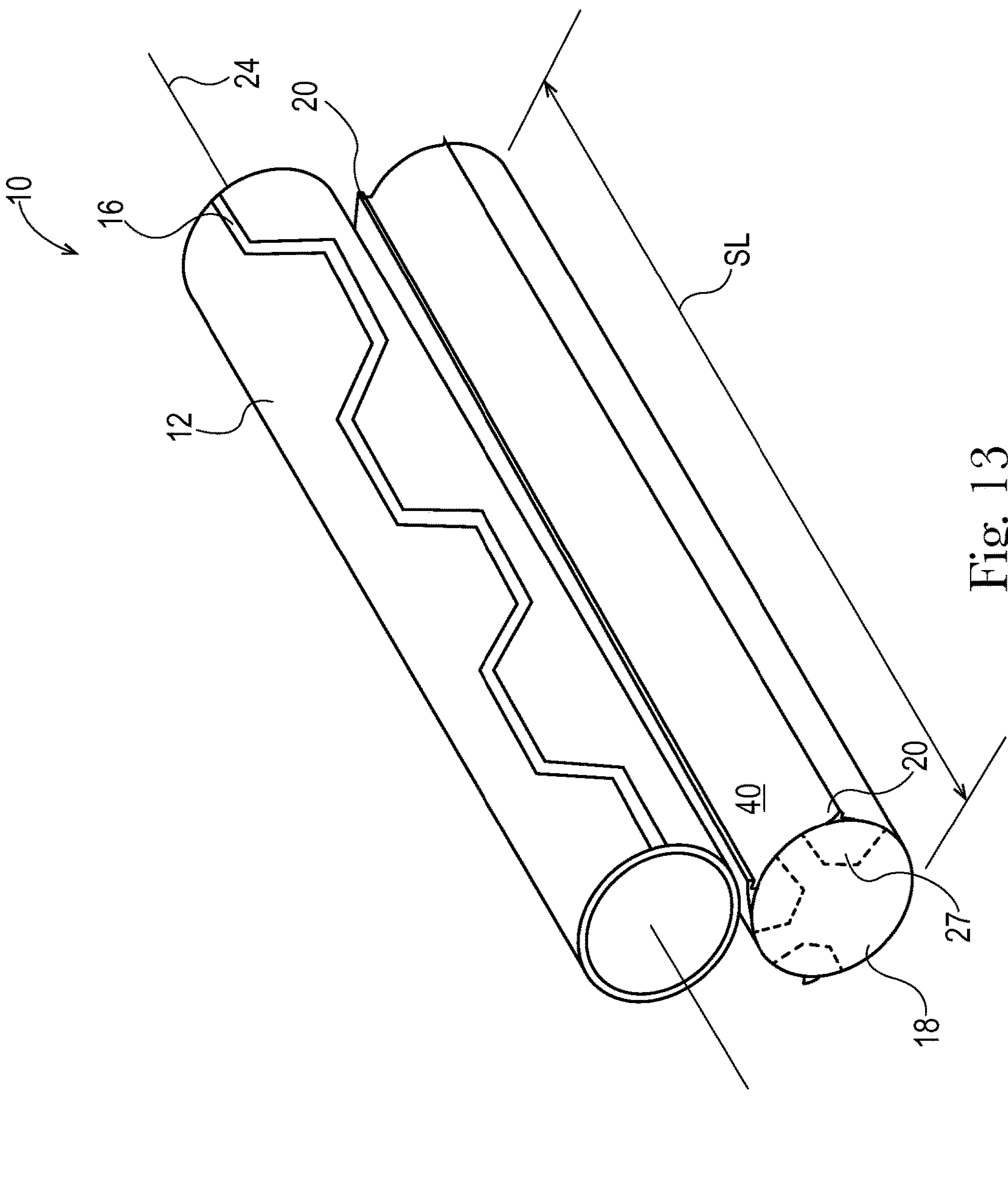

Fig. 13

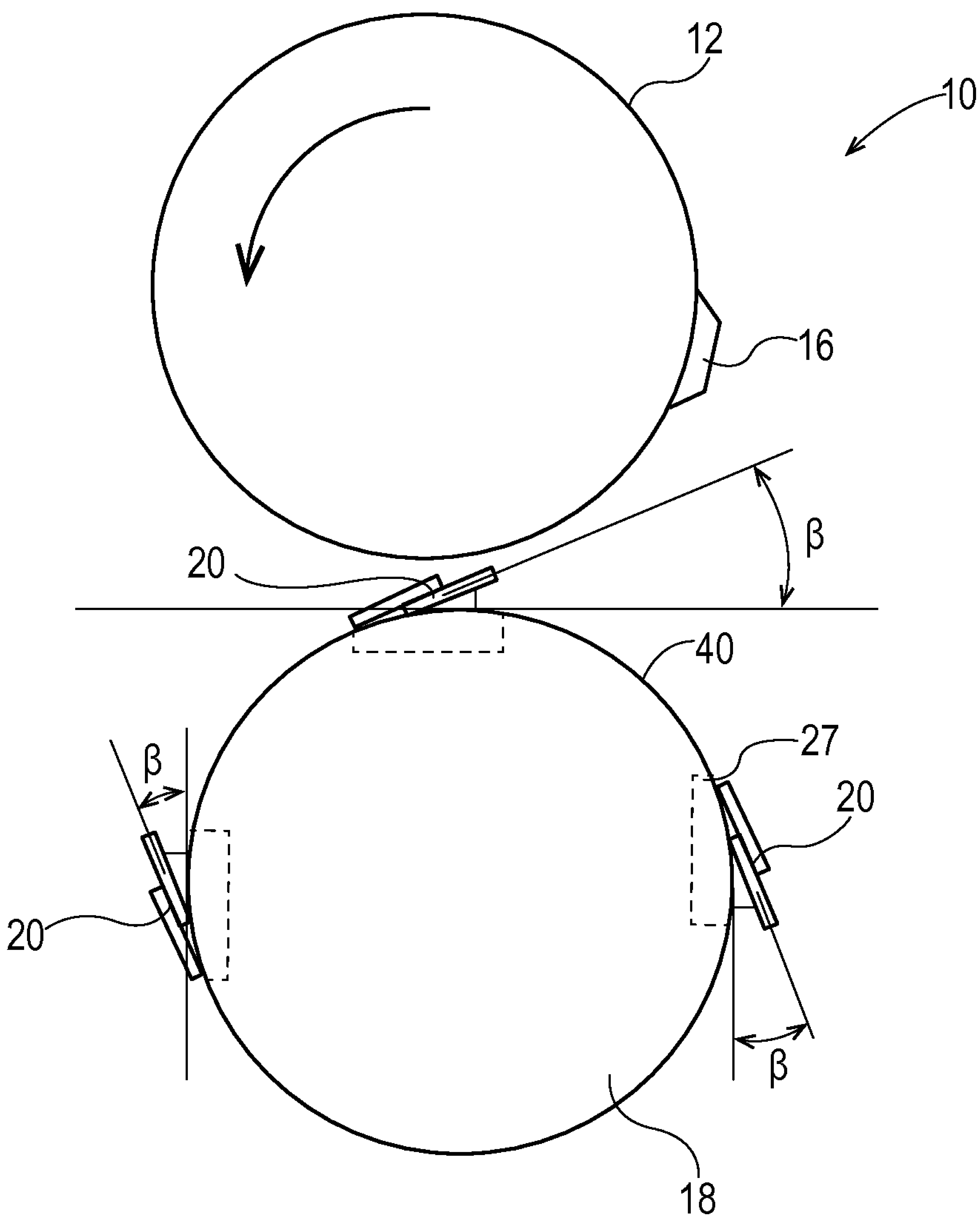

Fig. 14

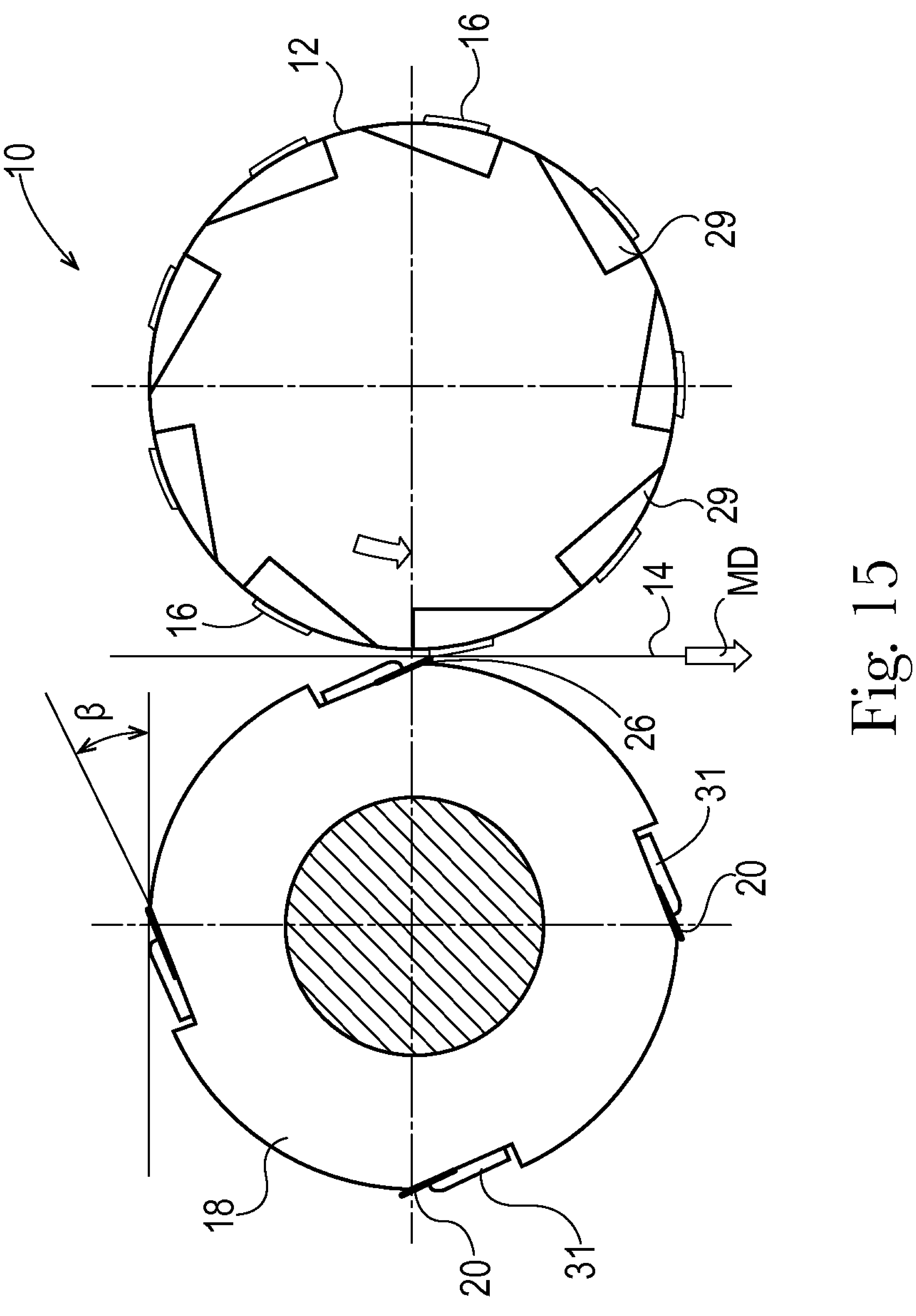

Fig. 15

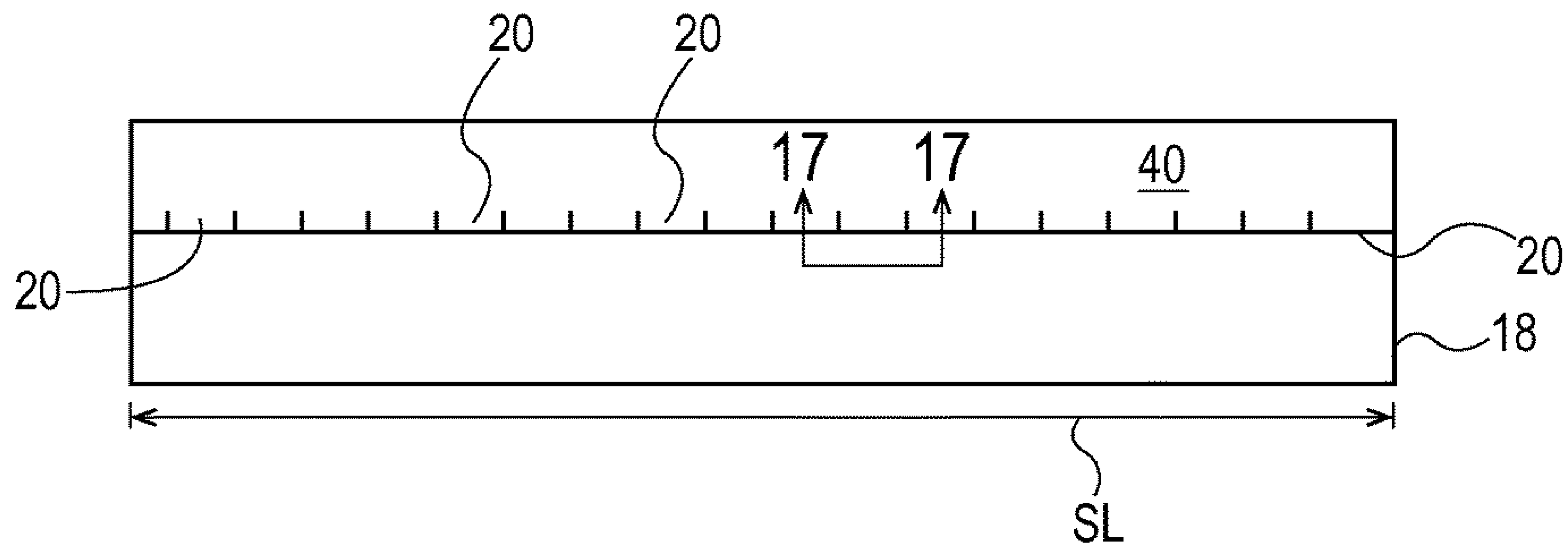

Fig. 16

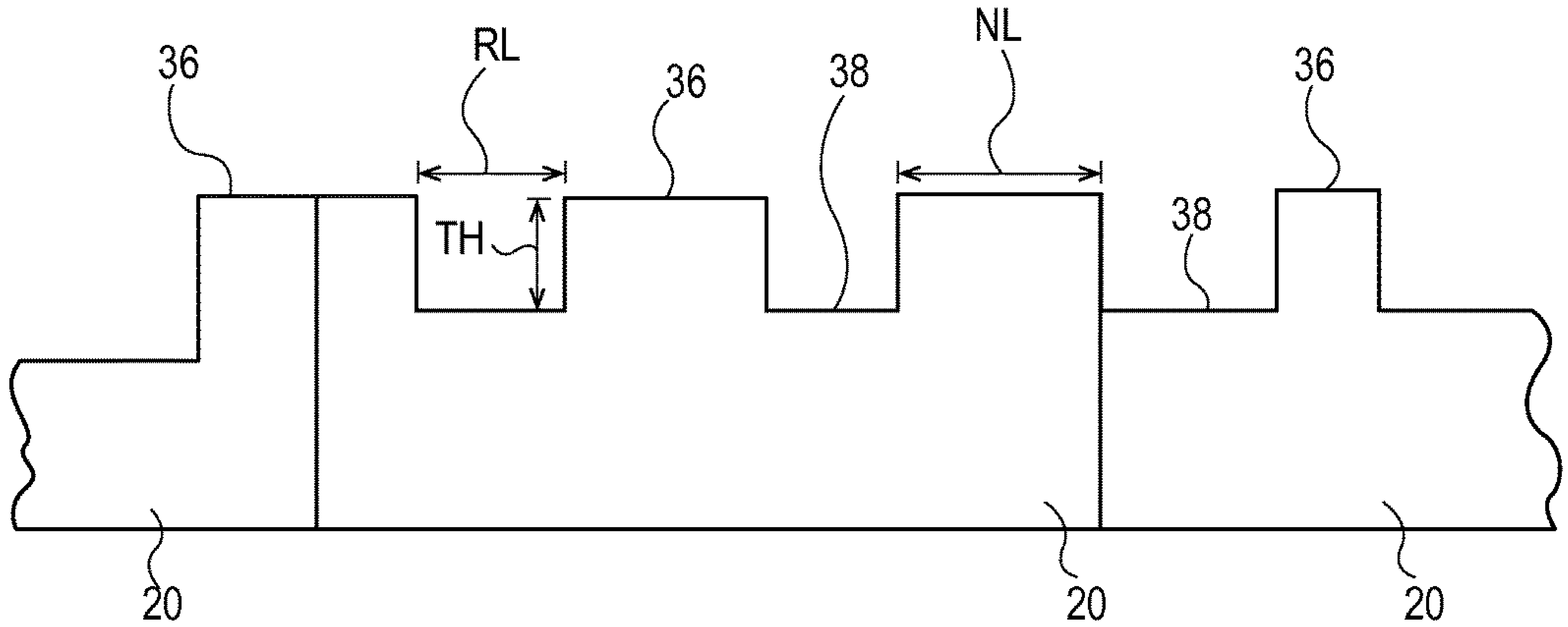

Fig. 17

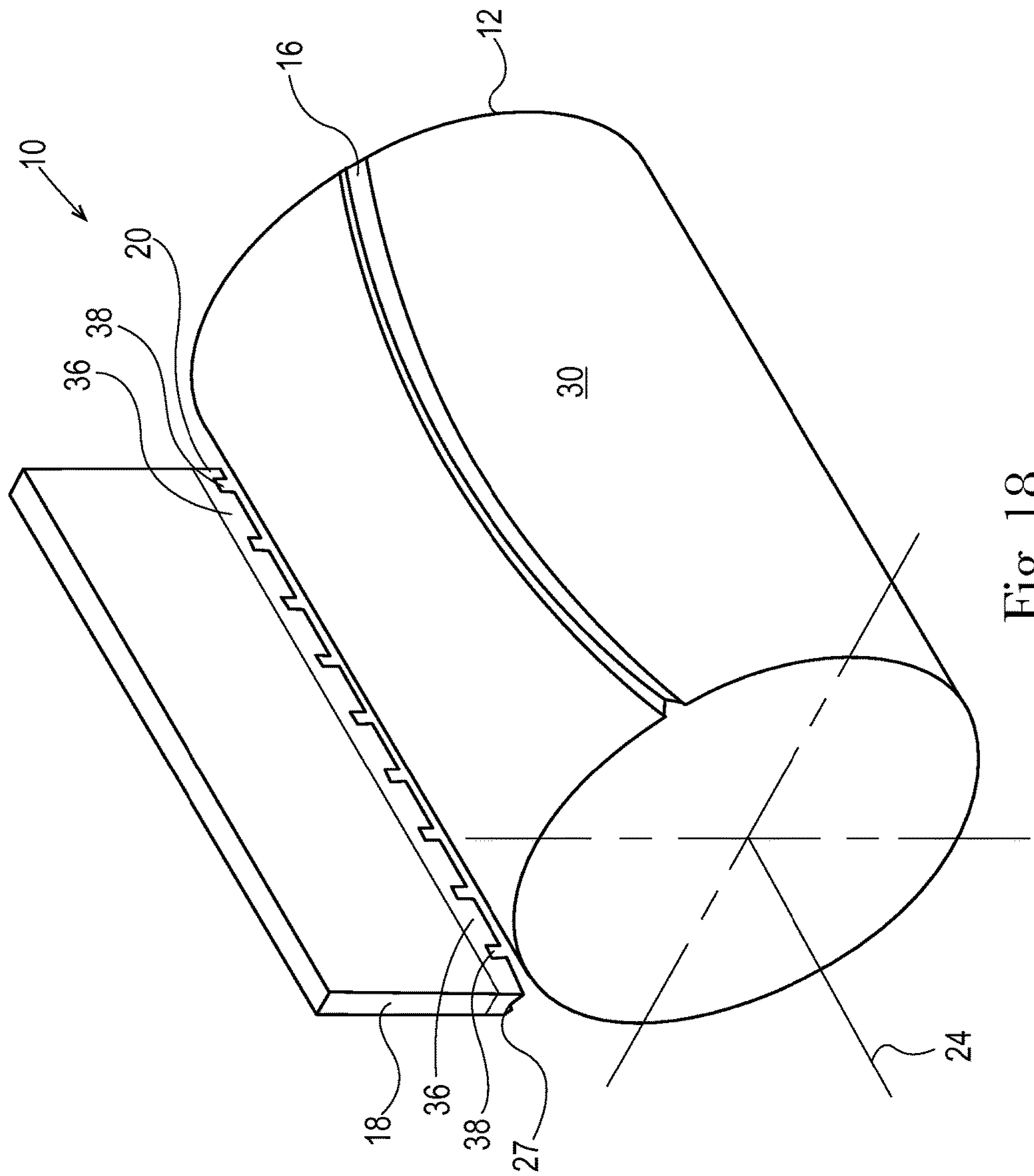

Fig. 18

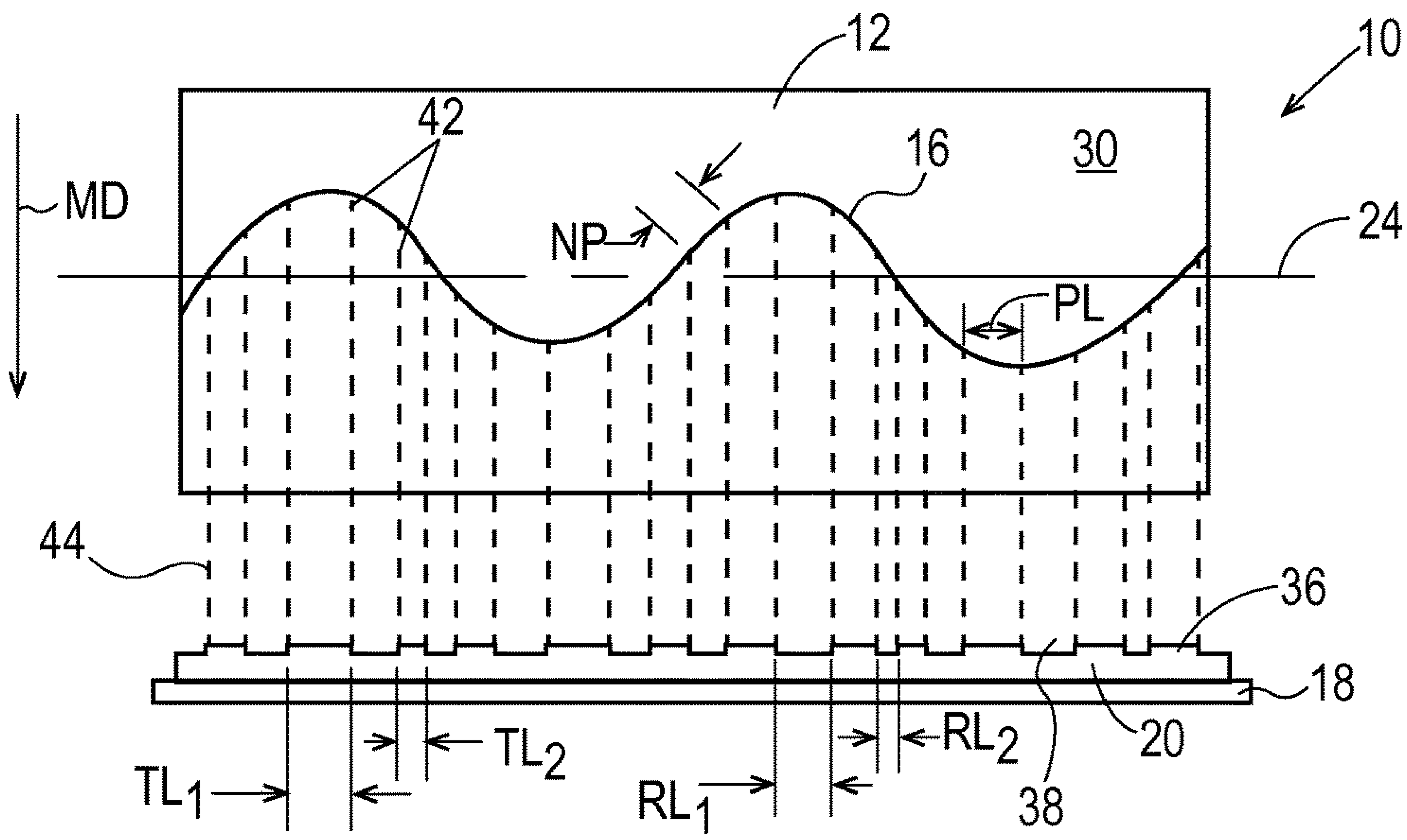

Fig. 19

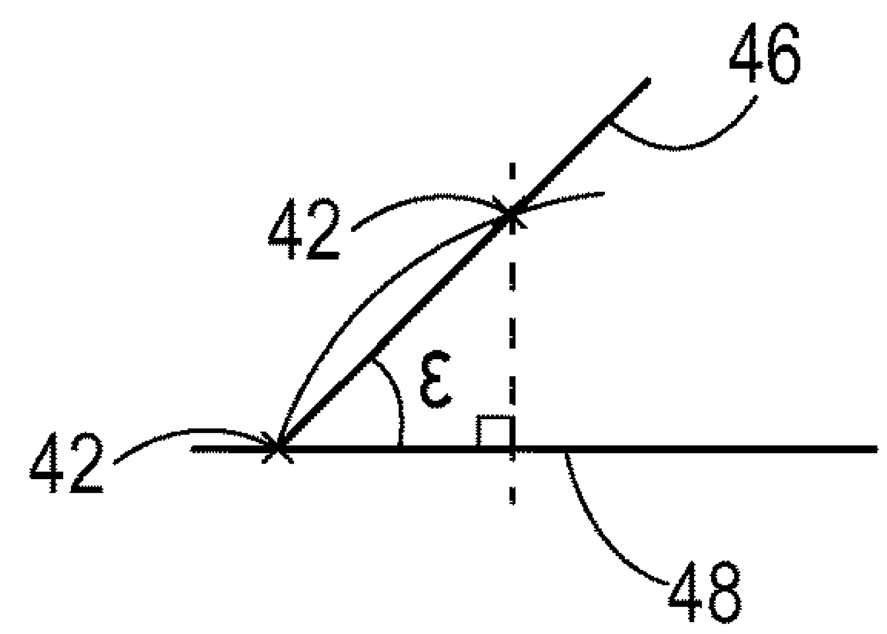

Fig. 20

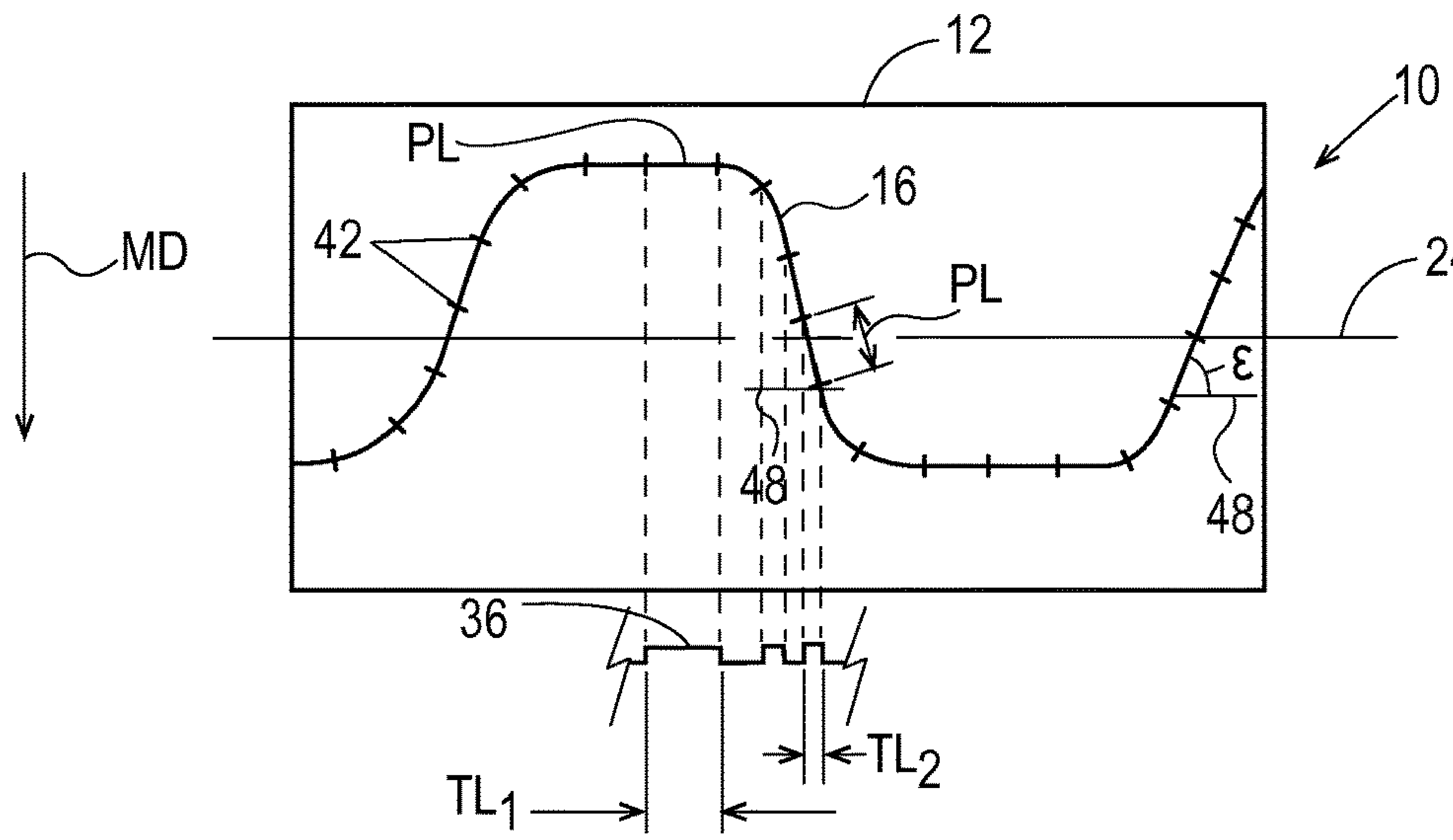

Fig. 21

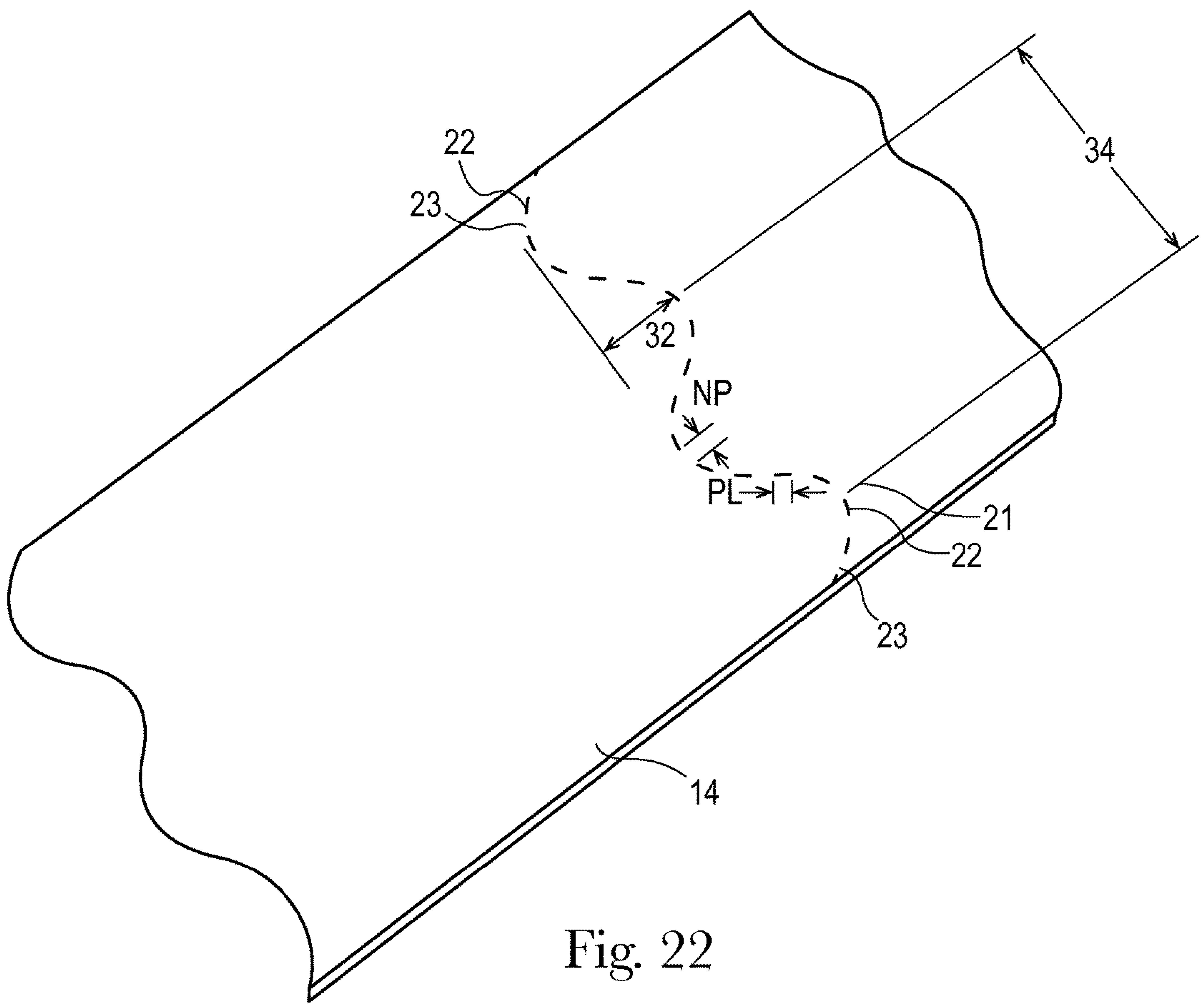

Fig. 22

Fig. 23A

Fig. 23B

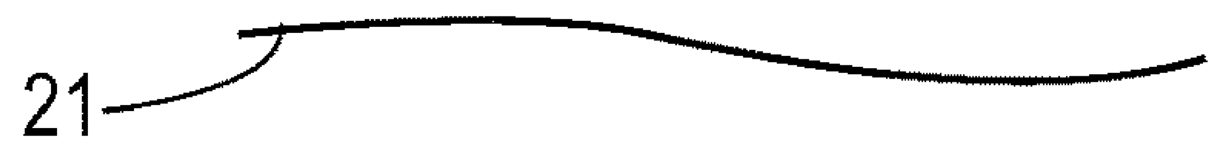

Fig. 23C

Fig. 23D

Fig. 23E

Fig. 23F

Fig. 23G

Fig. 23H

Fig. 23I

Fig. 23J

Fig. 23K

Fig. 23L

Fig. 23M

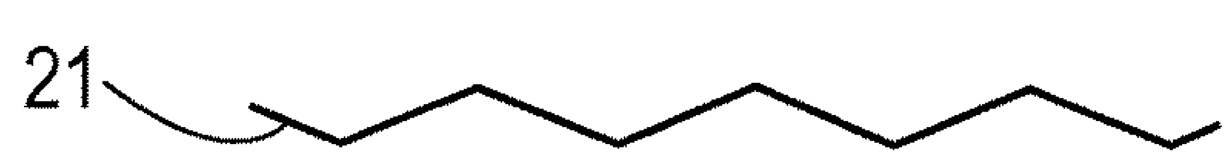

Fig. 23N

Fig. 23O

Fig. 23P

Fig. 23Q

NONLINEAR LINE OF WEAKNESS FORMED BY A PERFORATING APPARATUS

FIELD OF THE INVENTION

The present disclosure relates to nonlinear lines of weakness for rolled products, and more specifically, relates to a web comprising a nonlinear line of weakness comprising one or more perforations and one or more bond areas.

BACKGROUND

Many articles and packages include or can include a strip of material that has a line of weakness having one or more perforations to aid in tearing the article or package. For example, articles can include wax paper, aluminum foil, disposable bags, and sanitary tissue products, such as toilet tissue, facial tissue, and paper towels manufactured in the form of a web. Sanitary tissue products include lines of weakness to permit tearing off discrete sheets, for example, as is well known in the art. Such products are commonly used in households, businesses, restaurants, shops, and the like.

Typically, a line of weakness consists of a straight perforation across the width of the web. Creating perforations at high speeds and long widths is very challenging. Small vibrations in the equipment can result in non-perforated areas and/or inconsistent quality in the perforation and/or additional wear on the equipment. Further, tight tolerances between equipment must be maintained. Generally, there are three ways to perforate webs: die cutting, laser cutting, and flex blade cutting. Die cutting is a compression or crush cut in which a knife contacts a hardened anvil roll or a male roll interacts with a female roll to create one or more perforations. Die cutting usually is associated with high replacement costs and low speeds. Further die cutting does not allow for accuracy at long widths or mismatched speed operation. Similarly, laser cutting is a high-powered method to perforate webs. Laser cutting is usually used on thicker substrates and on cuts requiring a high degree of accuracy. Still further, flex blade cutting is a cut created by shearing the web. Flex blade cutting requires at least one blade to flex against a relatively stationary blade or anvil during operation to cut the web. Relative to the above cutting methods, flex blade cutting is generally lower cost, can be performed at higher speeds, and can be run at mismatched speeds. In addition to the above, water jet, steam, and spark aperture cutting methods can also be used to create lines of weakness. These methods have been found to be incompatible with the product being manufactured and/or inadequate for high speed, low cost production of perforated webs.

For example, using two rotating rolls to create a shaped line of weakness can be complex and expensive. The two rotating rolls must be matched to come together at exactly the right moment in time. Stated another way, the male roll must be synchronized with the female roll. Further, creating perforations with a rotating male roll and a rotating female roll can require a greater force be imparted to the web to create the line of weakness. Finally, the equipment to create such a line of weakness is large and must operate at lower speeds to maintain proper matching of the rolls.

It has been found that consumers desire products that are usable and have a distinguishing feature over other products. Manufacturers of various products, for example sanitary tissue products, desire that consumers of such products be able to readily distinguish their products from similar products produced by competitors. One way a manufacturer can distinguish its products from other products is to impart physical characteristics into the web that differ from other manufacturers' products. A shaped perforation is one distinguishing characteristic that can be added to the product. The shape of the line of weakness would not only provide a way for consumers to distinguish a manufacture's product, but also communicate to consumers a perception of luxury, elegance, and softness and/or strength.

Further, manufactures desire a shaped perforation that consumers of such products can easily and readily interact with. Often a straight perforation on a sanitary tissue product, for example, can rest directly on the adjacent layer making it difficult to see the end of the sheet. This can make it difficult for a user to locate, grasp, and/or dispense the product. A straight perforation can allow for only a single plane of the product on which a user can grasp for dispensing.

However, producing a web with a shaped perforation adds more complexity to the manufacturing process. As previously stated, tight tolerances and minimal to no vibration are required in manufacturing a line of weakness at the high speeds necessary for commercial viability. Thus, adding a shape to the anvil and/or the blade can increase the risk of introducing processing complexities and complications into commercial manufacturing operations for a perforated web.

Still further, as previously stated, consumers desire a product that they can easily and readily interact with. A shaped perforation adds a degree of complexity to the processing capability of manufactures to provide a product that tears at least as well as a currently marketed product having a straight line of weakness. Further, imparting a shaped line of weakness in the product can lead to unequal perforations and/or inconsistency in tearing.

Accordingly, there is a continuing unmet need for an improved perforating apparatus to manufacture a web with a shaped line of weakness.

Accordingly, there is a continuing unmet need for an improved method to manufacture a web with a shaped line of weakness.

Still further, there is a continuing unmet need for a sanitary tissue product having individual sheets separated by shaped lines of weakness, and which allows consumers to easily and readily interact with the product. More specifically, there is a continuing unmet need for a sanitary tissue product that allows the consumer to grasp the first, exposed sheet of the product readily and easily for dispensing and use.

SUMMARY

In one example embodiment, a web can comprise a curvilinear line of weakness. The curvilinear line of weakness can comprise a plurality of perforations. Each of the plurality of perforations can be separated by a bond area. Further, each of the plurality of perforations can have a perforation length and each bond area can have a non-perforation length, and at least two of the perforations lengths can be substantially equal.

In another example embodiment, a web can comprise a curvilinear line of weakness. The curvilinear line of weakness can comprise a plurality of perforations. Each of the plurality of perforations can be separated by a bond area. Each of the plurality of perforations can have a perforation length and each bond area can have a non-perforation length, and at least two of the non-perforations lengths can be substantially equal.

In yet another example embodiment, a web can comprise a curvilinear line of weakness. The curvilinear line of weakness can comprise a plurality of perforations. Each of the plurality of perforations can be separated by a bond area. Each of the plurality of perforations can have a perforation length and each bond area can have a non-perforation length, and at least two of the non-perforations lengths can be substantially unequal and at least two of the perforation lengths can be substantially unequal.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features and advantages of this disclosure, and the manner of attaining them, will become more apparent and the disclosure itself will be better understood by reference to the following description of non-limiting embodiments of the disclosure taken in conjunction with the accompanying drawings, wherein:

FIG. **1** is a perspective view of a perforating apparatus in accordance with one non-limiting embodiment of the present disclosure;

FIG. **2** is a partial side elevation view of a perforating apparatus in accordance with one non-limiting embodiment of the present disclosure;

FIG. **3** is a partial side elevation view of a perforating apparatus in accordance with one non-limiting embodiment of the present disclosure;

FIG. **4** is a partial side elevation view of a perforating apparatus in accordance with one non-limiting embodiment of the present disclosure;

FIG. **4**A is a side elevation view of an anvil disposed on a cylinder in accordance with one non-limiting embodiment of the present disclosure;

FIG. **5** is a front elevation view of an anvil disposed on a cylinder in accordance with one non-limiting embodiment of the present disclosure;

FIG. **5**A is a side elevation view of an anvil disposed on a cylinder in accordance with one non-limiting embodiment of the present disclosure;

FIGS. **5**B-G are a cross sectional view of Section **5**B-G of FIG. **5**;

FIG. **6** is a front elevation view of an anvil disposed on cylinder in accordance with one non-limiting embodiment of the present disclosure;

FIG. **7** is a front elevation view of an anvil disposed on cylinder in accordance with one non-limiting embodiment of the present disclosure;

FIG. **8** is a plan view of a web in position to be perforated by a perforating apparatus in accordance with one non-limiting embodiment of the present disclosure;

FIG. **9** is a plan view of a web in position to be perforated by a perforating apparatus in accordance with one non-limiting embodiment of the present disclosure;

FIGS. **10**-**10**R are schematic representations showing the progression of a web being perforated in accordance with one non-limiting embodiment of the present disclosure;

FIG. **11** is a perspective view of a perforating apparatus in accordance with one non-limiting embodiment of the present disclosure;

FIG. **12** is a schematic representation of a notched anvil in accordance with one non-limiting embodiment of the present disclosure;

FIG. **13** is a perspective view of a perforating apparatus in accordance with one non-limiting embodiment of the present disclosure;

FIG. **14** is a partial side elevation view of a perforating apparatus in accordance with one non-limiting embodiment of the present disclosure;

FIG. **15** is a partial side elevation view of a perforating apparatus in accordance with one non-limiting embodiment of the present disclosure;

FIG. **16** is a front elevation view of a blade disposed on a support in accordance with one non-limiting embodiment of the present disclosure;

FIG. **17** is a cross sectional view of Section **17**-**17** of FIG. **16**;

FIG. **18** is a perspective schematic representation of a perforating apparatus in accordance with one non-limiting embodiment of the present disclosure;

FIG. **19** is a schematic representation of a notched blade disposed on a support and a shaped anvil disposed in a cylinder in accordance with one non-limiting embodiment of the present disclosure;

FIG. **20** is a schematic representation of a portion of an anvil indicating perforating length or non-perforating length to determine the tooth length or recessed portion length in accordance with one non-limiting embodiment of the present disclosure;

FIG. **21** is a schematic representation of a notched blade disposed on a support and a shaped anvil disposed in a cylinder in accordance with one non-limiting embodiment of the present disclosure;

FIG. **22** is a perspective view of a web in accordance with one non-limiting embodiment of the present disclosure; and

FIGS. **23**A-Q are schematic representations of the shape of a line of weakness in accordance with one non-limiting embodiment of the present disclosure.

DETAILED DESCRIPTION

Various non-limiting embodiments of the present disclosure will now be described to provide an overall understanding of the principles of the structure, function, manufacture, and use of a web comprising a shaped line of weakness. The features illustrated or described in connection with one non-limiting embodiment can be combined with the features of other non-limiting embodiments. Such modifications and variations are intended to be included within the scope of this disclosure.

"Fibrous structure" as used herein means a structure that comprises one or more fibrous elements. In one example, a fibrous structure according to the present disclosure means an association of fibrous elements that together form a structure capable of performing a function. A nonlimiting example of a fibrous structure of the present disclosure is an absorbent paper product, which can be a sanitary tissue product such as a paper towel, bath tissue, or other rolled, absorbent paper product.

Non-limiting examples of processes for making fibrous structures include known wet-laid papermaking processes, air-laid papermaking processes, and wet, solution, and dry filament spinning processes, for example meltblowing and spunbonding spinning processes, that are typically referred to as nonwoven processes. Such processes can comprise the steps of preparing a fiber composition in the form of a suspension in a medium, either wet, more specifically aqueous medium, or dry, more specifically gaseous, i.e. with air as medium. The aqueous medium used for wet-laid processes is oftentimes referred to as fiber slurry. The fibrous suspension is then used to deposit a plurality of fibers onto a forming wire or belt such that an embryonic fibrous structure is formed, after which drying and/or bonding the fibers together results in a fibrous structure. Further processing the fibrous structure can be carried out such that a finished fibrous structure is formed. For example, in typical papermaking processes, the finished fibrous structure is the fibrous structure that is wound on the reel at the end of papermaking and can subsequently be converted into a finished product (e.g., a sanitary tissue product).

"Fibrous element" as used herein means an elongate particulate having a length greatly exceeding its average diameter, i.e. a length to average diameter ratio of at least about 10. A fibrous element may be a filament or a fiber. In one example, the fibrous element is a single fibrous element rather than a yarn comprising a plurality of fibrous elements.

The fibrous elements of the present disclosure may be spun from polymer melt compositions via suitable spinning operations, such as meltblowing and/or spunbonding and/or they may be obtained from natural sources such as vegetative sources, for example trees.

The fibrous elements of the present disclosure may be monocomponent and/or multicomponent. For example, the fibrous elements may comprise bicomponent fibers and/or filaments. The bicomponent fibers and/or filaments may be in any form, such as side-by-side, core and sheath, islands-in-the-sea and the like.

"Filament" as used herein means an elongate particulate as described above that exhibits a length of greater than or equal to 5.08 cm (2 in.) and/or greater than or equal to 7.62 cm (3 in.) and/or greater than or equal to 10.16 cm (4 in.) and/or greater than or equal to 15.24 cm (6 in.).

Filaments are typically considered continuous or substantially continuous in nature. Filaments are relatively longer than fibers. Non-limiting examples of filaments include meltblown and/or spunbond filaments. Non-limiting examples of polymers that can be spun into filaments include natural polymers, such as starch, starch derivatives, cellulose, such as rayon and/or lyocell, and cellulose derivatives, hemicellulose, hemicellulose derivatives, and synthetic polymers including, but not limited to polyvinyl alcohol, thermoplastic polymer, such as polyesters, nylons, polyolefins such as polypropylene filaments, polyethylene filaments, and biodegradable thermoplastic fibers such as polylactic acid filaments, polyhydroxyalkanoate filaments, polyesteramide filaments and polycaprolactone filaments.

"Fiber" as used herein means an elongate particulate as described above that exhibits a length of less than 5.08 cm (2 in.) and/or less than 3.81 cm (1.5 in.) and/or less than 2.54 cm (1 in.). A fiber can be elongate physical structure having an apparent length greatly exceeding its apparent diameter (i.e., a length to diameter ratio of at least about 10.) Fibers having a non-circular cross-section and/or tubular shape are common; the "diameter" in this case can be considered to be the diameter of a circle having a cross-sectional area equal to the cross-sectional area of the fiber.

Fibers are typically considered discontinuous in nature. Non-limiting examples of fibers include pulp fibers, such as wood pulp fibers, and synthetic staple fibers such as polypropylene, polyethylene, polyester, copolymers thereof, rayon, glass fibers and polyvinyl alcohol fibers.

Staple fibers may be produced by spinning a filament tow and then cutting the tow into segments of less than 5.08 cm (2 in.) thus producing fibers.

In one example of the present disclosure, a fiber may be a naturally occurring fiber, which means it is obtained from a naturally occurring source, such as a vegetative source, for example a tree and/or other plant. Such fibers are typically used in papermaking and are oftentimes referred to as papermaking fibers. Papermaking fibers useful in the present disclosure include cellulosic fibers commonly known as wood pulp fibers. Applicable wood pulps include chemical pulps, such as Kraft, sulfite, and sulfate pulps, as well as mechanical pulps including, for example, groundwood, thermomechanical pulp and chemically modified thermomechanical pulp. Chemical pulps, however, may be preferred since they impart a superior tactile sense of softness to fibrous structures made therefrom. Pulps derived from both deciduous trees (hereinafter, also referred to as "hardwood") and coniferous trees (hereinafter, also referred to as "softwood") may be utilized. The hardwood and softwood fibers can be blended, or alternatively, can be deposited in layers to provide a stratified web. Also applicable to the present disclosure are fibers derived from recycled paper, which may contain any or all of the above categories of fibers as well as other non-fibrous polymers such as fillers, softening agents, wet and dry strength agents, and adhesives used to facilitate the original papermaking

In addition to the various wood pulp fibers, other cellulosic fibers such as cotton linters, rayon, lyocell, and bagasse fibers can be used in the fibrous structures of the present disclosure.

"Sanitary tissue product" as used herein means one or more finished fibrous structures, that is useful as a wiping implement for post-urinary and post-bowel movement cleaning (e.g., toilet tissue, also referred to as bath tissue, and wet wipes), for otorhinolaryngological discharges (e.g., facial tissue), and multi-functional absorbent and cleaning and drying uses (e.g., paper towels, shop towels). The sanitary tissue products can be embossed or not embossed and creped or uncreped.

In one example, sanitary tissue products rolled about a fibrous core of the present disclosure can have a basis weight between about 10 g/m^2 to about 160 g/m^2 or from about 20 g/m^2 to about 150 g/m^2 or from about 35 g/m^2 to about 120 g/m^2 or from about 55 to 100 g/m^2, specifically reciting all 0.1 g/m^2 increments within the recited ranges. In addition, the sanitary tissue products can have a basis weight between about 40 g/m^2 to about 140 g/m^2 and/or from about 50 g/m^2 to about 120 g/m^2 and/or from about 55 g/m^2 to about 105 g/m^2 and/or from about 60 to 100 g/m^2, specifically reciting all 0.1 g/m^2 increments within the recited ranges. Other basis weights for other materials, such as wrapping paper and aluminum foil, are also within the scope of the present disclosure.

"Basis Weight" as used herein is the weight per unit area of a sample reported in lbs/3000 ft^2 or g/m^2. Basis weight can be measured by preparing one or more samples to create a total area (i.e., flat, in the material's non-cylindrical form) of at least 100 in^2 (accurate to +/−0.1 in^2) and weighing the sample(s) on a top loading calibrated balance with a resolution of 0.001 g or smaller. The balance is protected from air drafts and other disturbances using a draft shield. Weights are recorded when the readings on the balance become constant. The total weight (lbs or g) is calculated and the total area of the samples (ft^2 or m^2) is measured. The basis weight in units of lbs/3,000 ft^2 is calculated by dividing the total weight (lbs) by the total area of the samples (ft^2) and multiplying by 3000. The basis weight in units of g/m^2 is calculated by dividing the total weight (g) by the total area of the samples (m^2).

"Density" as used hereing is calculated as the quotient of the Basis Weight expressed in grams per square meter divided by the Caliper expressed in microns. The resulting Density is expressed as grams per cubic centimeter (g/cm^3 or g/cc). Sanitary tissue products of the present disclosure can have a density of greater than about 0.05 g/cm^3 and/or greater than 0.06 g/cm^3 and/or greater than 0.07 g/cm^3 and/or less than 0.10 g/cm^3 and/or less than 0.09 g/cm^3 and/or less than 0.08 g/cm^3 and/or less than 0.60 g/cm^3 and/or less than 0.30 g/cm^3 and/or less than 0.20 g/cm^3 and/or less than 0.15 g/cm^3 and/or less than 0.10 g/cm^3 and/or less than 0.07 g/cm^3 and/or less than 0.05 g/cm^3 and/or from about 0.01 g/cm^3 to about 0.20 g/cm^3 and/or from about 0.02 g/cm^3 to about 0.15 g/cm^3 and/or from about 0.02 g/cm^3 to about 0.10 g/cm^3.

"Ply" as used herein means an individual, integral fibrous structure.

"Plies" as used herein means two or more individual, integral fibrous structures disposed in a substantially contiguous, face-to-face relationship with one another, forming a multi-ply fibrous structure and/or multi-ply sanitary tissue product. It is also contemplated that an individual, integral fibrous structure can effectively form a multi-ply fibrous structure, for example, by being folded on itself.

"Rolled product(s)" as used herein include plastics, fibrous structures, paper, sanitary tissue products, paperboard, polymeric materials, aluminum foils, and/or films that are in the form of a web and can be wound about a core. For example, the sanitary tissue product can be convolutedly wound upon itself about a core or without a core to form a sanitary tissue product roll or can be in the form of discrete sheets, as is commonly known for toilet tissue and paper towels.

"Machine Direction," MD, as used herein is the direction of manufacture for a perforated web. The machine direction can be the direction in which a web is fed through a perforating apparatus that can comprise a rotating cylinder and support, as discussed below in one embodiment. The machine direction can be the direction in which web travels as it passes through a blade and an anvil of a perforating apparatus.

"Cross Machine Direction," CD as used herein is the direction substantially perpendicular to the machine direction. The cross machine direction can be substantially perpendicular to the direction in which a web is fed through a cylinder and lower support in one embodiment. The cross machine direction can be the direction substantially perpendicular to the direction in which web travels as it passes through a blade and an anvil.

Referring to FIG. **1**, a perforating apparatus **10** is shown for forming a shaped line of weakness **21** comprising one or more perforations **22** on a web **14**. The perforating apparatus **10** comprises a cylinder **12** and a support **18**. The cylinder **12** can be suspended between one or more braces **28** that serve to hold cylinder **12** in operative position. The cylinder **12** has a longitudinal cylinder axis **24** about which the cylinder **12** is rotatable. The cylinder **12** can have a substantially circular shaped cross-section or oval-like shaped cross-section or any other shaped cross-section that can rotate about an axis and operatively engage a support **18**. The cylinder **12** can comprise an outer surface **30** positioned radially outward from and substantially surrounding the longitudinal cylinder axis **24**.

The cylinder **12** can comprise an anvil **16**. In one example embodiment, the anvil **16** can be disposed on the outer surface **30** of the cylinder **12**. In another example embodiment, the anvil **16** can be disposed on an anvil insert **29** that can be removably attached to the cylinder **12**. The anvil insert **29** can be magnetically attached to the outer surface **30** of the cylinder **12**. In another embodiment, the anvil insert **29** can be chemically attached, such as by glue, or mechanically attached, such as by clamping, bolting, or otherwise joining to the outer surface **30** of the cylinder **12**. Opposite the cylinder **12**, the support **18** can comprise a blade **20**. The blade **20** can be disposed on the support **18**. By "disposed" is meant the blade can be attached, removeably attached, clamped, bolted, or otherwise held by the support **18** in a stable operative position with respect to the cylinder **12**.

In another example embodiment, the support **18** can comprise a blade holder **27**. The blade **20** can be disposed on the blade holder **27** in such a manner as to maintain sufficient stability when in contacting engagement with the anvil **16**. Further, a clamp **31**, shown in FIG. **2**, can be disposed on the blade holder **27** and partially surround the blade **20**. The clamp **31** can be designed generally as indicated in FIG. **2** with the blade being held between two parts of the clamp that can each flex relative to the other. In this manner the clamp **31** can removably hold the blade **20** such that the blade **20** can deflect when it contacts the anvil **16**. This deflection and the inherent flexibility of the blade **20** allows for improved perforation reliability by being more forgiving to slight differences in machine tolerances. Thus, the support **18** serves to hold the blade holder **27**, which can include a clamp **31**, and thus the blade **20**, in a relatively stable orientation during operation.

The cylinder **12** is moveable such that the cylinder **12** can operatively engage with the support **18**. Operative engagement means the support **18** can be arranged in relationship to the cylinder **12** such that the blade **20** can make contact with the anvil **16** as it rotates past the blade **20**; the contact sufficient to make one or more perforations **22** in a web **14**. In one embodiment, the contact between the anvil **16** and the blade **20** is a shearing action. Thus, in one embodiment, the perforating apparatus can be a shear-cutting device. The blade **20** can be disposed on the support **18** so as to cooperate in contacting relationship with the anvil **20** disposed on the cylinder **12** to impart a line of weakness **21** comprising one or more perforations **22** and one or more bond areas **23** in the web **14**. The bond areas **23** are the portion of the web between two adjacent perforations. The inventors found a unique and surprising result from shaping the element disposed on the rotating cylinder **12**. In one embodiment, the shaped element can comprise the anvil **16**. The resulting perforation on the sheet takes on the same or a similar shape as the shaped rotating element, which, in one embodiment is a shaped anvil **16**. The same result does not occur if the shape is not on the rotating roll.

As previously stated, the line of weakness **21** comprising perforations **22** and bond areas **23** can be the shape of the anvil **16**. The characteristics of the one or more perforations **22** and bond areas **23** can be due, in part, to the interaction point **26**. Referring to FIGS. **1-4**, the interaction point **26** is the point where contact occurs between the anvil **16** and blade **20**. The characteristics of the perforations **22** can be a result of the amount of overlap between the blade **20** and anvil **16** and how the blade **20** and the anvil **16** cooperate in contacting relationship. For example, the blade **20** against the anvil **16** can result in a shearing action that imparts certain characteristics to the perforations **22**. In one embodiment, the interaction point **26** can be adjusted by moving the support **18** and/or the cylinder **12**. In an alternative embodiment, the interaction point **26** can be adjusted by moving the anvil insert **29** on which the anvil **16** is disposed and/or the blade holder **27** and/or the clamp **31** on which the blade **20** can be disposed. Thus, the interaction point **26** can be increased or decreased, which alters the characteristics of the resulting line of weakness **21** imparted to the web **14** and, thus, the characteristics of each perforation **22** and bond area **23**. The interaction point **26**, the overlap of the blade **20** operatively engaging the anvil **16**, can be from about 0.0001 inches to about 0.01 inches and/or from about 0.0005 inches to about 0.009 inches, including all 1/10000 of an inch therebetween. For example, an overlap of 0.0006 inches would be covered in the above range. By increasing the overlap between the blade **20** and the anvil **16**, the perforations **22** generally become more pronounced, more visible, crisper and longer. By decreasing the overlap between the blade **20** and the anvil **16**, the perforations **22** generally become less pronounced, less visible, shorter, and the bond **23** becomes wider and thus stronger. Thus, the interaction point **26** can be an important design consideration to create a line of weakness **21** comprising a plurality of perforations **22** and bond areas **23** between adjacent perforations **22** that allow the sheets to be held together during the manufacturing process and easily separated by consumers during use.

As stated above, the anvil **16** and the blade **20** cooperate in contacting relationship. Generally, the anvil **16** can be a substantially hardened steel surface such that there is little to no deflection of the anvil **16** as it cooperates with the blade **20**. By contrast, as the blade **20** cooperates with the anvil **16**, the blade **20** can deflect against the anvil **16** creating a line of weakness **21** in the web **14**. In one embodiment, the clamp **31** can be designed such that it allows the blade **20** to flex as it interacts with the anvil **16**. More specifically, as shown in FIG. **2**, the clamp **31** can be designed with an opening that allows at least a portion of the clamp **31** (for example, the lower portion shown in FIG. **2**) to move as the blade **20** interacts with the anvil **16**. Alternatively, the clamp **31** can be designed such that the blade **20** remains substantially rigid as it interacts with the anvil **16**. The rigidity/flexibility of the blade **20** against the anvil **16** can also alter the characteristics of the resulting line of weakness **21** imparted to the web **14**, and, thus, the characteristics of each perforation **22** and bond area **23**. The line of weakness **21** can be imparted to the web **14** in the cross machine direction CD as the web **14** proceeds through the perforating apparatus **10** in the machine direction MD.

Referring to FIGS. **1-3**, the support **18** can be positioned in a number of orientations relative to the cylinder **12** and still result in the anvil **16** operatively engaging the blade **20**. As shown in FIG. **1**, the support **18** can be positioned below the cylinder **12** as the web **14** is perforated. In another embodiment, as shown in FIG. **2**, the cylinder **12** can be positioned below the support **18**. In yet another embodiment, the cylinder **12** and the support **18** can be positioned side by side, as shown in FIG. **3**. The support **18** and cylinder **12** can be placed in any position relative to one another that allows for the blade **20** and anvil **16** to cooperate in contacting relationship to form a line of weakness **21** across the width of web **14**. Stated another way, the support **18** and the cylinder **12** can be placed in any position relative to one another such that an interaction point **26** exists between the blade **20** and the anvil **16** sufficient to form a line of weakness **21** across the width of web **14**. Alternatively or in addition to the adjustment of the support **18** and the cylinder **12**, the anvil insert **29** and/or the blade holder **27** and/or the clamp **31** can be adjusted with respect to one another such that an interaction point **26** exists between the blade **20** and the anvil **16** sufficient to form a line of weakness **21** across the web **14**. In one embodiment, for example, the blade **20** can be adjusted in the clamp **31** such that the blade **20** forms an interaction point **26** with each anvil **16** disposed about the cylinder **12**.

The cylinder **12** can be a solid or substantially hollow cylindrical shaped device having a hardened outer surface **30**. The cylinder **12** can be formed of metal, such as steel, or some other material known to those skilled in the art to be suitable for use in forming perforations in a web. The outer surface **30** can be substantially smooth apart from or including the anvil **16**. The cylinder has a length L, as shown in FIG. **1**, and a diameter D, as shown in FIG. **4**. The diameter D and the Length L can be sized to handle the length and width of a web **14** that can pass over the outer surface **30** of cylinder **12**. For example, in one embodiment, a web can comprise a finished fibrous structure having a substantially continuous length, a width of about 10 inches to about 125 inches, and a thickness of about 0.009 inches to about 0.070 inches. Alternatively, the length L of the cylinder **12** can be sized to be substantially the same length as the support **18**, such that the blade **20** can operatively engage the anvil **16** along its full length. In one embodiment, the cylinder **12** can have a diameter D of about 5 inches to about 20 inches and/or about 8 inches to about 15 inches. The cylinder **12** can have a length L of about 10 inches to about 150 inches.

The cylinder **12** can comprise at least one anvil **16** disposed on the outer surface **30**, as illustrated in FIGS. **1-5**. The anvil **16** can protrude above the outer surface **30**, that is extend radially outward from the surface **30**. The anvil **16** can be made from one or more of tool steel, carbon steel, aluminum, ceramic, hard plastic or other suitable material. The anvil **16** can be coated with materials to enhance its strength and wear resistance (also referred to as machine life). For example, in one embodiment, the anvil **16** can be subject to plasma-enhanced chemical vapor deposition to deposit a thin film of material on the surface of the anvil **16**. Materials that can be used to prolong the machine life of the anvil **16** can include titanium oxide and ceramic coatings. The anvil **16** can be fixed to or removably attached to the outer surface **30**. For example, in one embodiment, the outer surface **30** can be machined to form an anvil **16** by effectively removing material from the outer surface **30**. In an alternative embodiment, an anvil **16** can be a separate member that can be inserted and removably attached to the cylinder **12**, as shown in FIGS. **2**, **3**, and **5**. The anvil **16** can be disposed on an anvil insert **29**, which can be removably attached to the outer surface **30** of the cylinder **12**. In one embodiment, the anvil **16** can be machined from the surface of the anvil insert **29**. In alternative embodiment, the anvil **16** can be removably attached mechanically, such as by bolting, clamping, or screwing, or chemically, such as by adhering to the anvil insert **29**.

A removably attached anvil **16** can aid in quickly changing out dull, worn, and/or damaged parts. Further, a removably attached anvil **16** can allow for easily changing from a straight perforation system to a shaped perforation system. In one example embodiment, the cylinder **12** can comprise an anvil **16** comprised of one or more anvil segments **17** positioned end-to-end along the length L of the cylinder **12**, as shown in FIG. **5**. Each anvil segment **17** can have a length sufficient for interacting with the blade **20** and/or easily removing segments for replacement. Thus, each individual anvil segment **17** can be removed and replaced independent of another anvil segments **17** disposed on the cylinder **12**. Each anvil segment **17** can be adjusted on the outer surface of the cylinder **12** to change how the anvil **16** contacts the blade **20** and perforates the web **14**. For example, a series of adjustment screws may be used to independently raise or lower the removably attached individual anvil segments **17** to facilitate an overall anvil **16** adjustment. Further, each anvil segment **17** can be positioned independent of another anvil segment **17** such that the blade **20** interacts differently with the different sections creating a line of weakness **21** having a plurality of perforations **22** and bond areas **23** with different characteristics, such as strength and/or size.

In addition to one or more anvil segments **17** being disposed end to end to extend along the length L of the cylinder **12**, one or more anvils **16** (each of which can comprise individual anvil segments **17** or a continuous single-piece anvil) can be spaced radially about the outer surface **30**, as shown in FIGS. **2-4**. The one or more anvils **16** can be spaced radially about the outer surface **30** such that each line of weakness **21** on the web **14** is produced at some desired distance from one another, which can result in a desired sheet length. For example, in one embodiment, a cylinder **12** having a diameter D of about 12 inches can comprise two anvils **16** spaced equidistant to one another around the outer surface **30** of the cylinder **12**. A web **14** can be fed through a perforating apparatus **10** comprising the cylinder **12** such that the machine direction MD of the web is substantially perpendicular to the longitudinal cylinder axis **24** of the cylinder **12**. In another embodiment, a web **14** can be fed through a perforating apparatus **10** comprising the cylinder **12** such that the machine direction MD of the web is at an angle to the longitudinal cylinder axis **24** of the cylinder **12**, which is disclosed in more detail below.

Successive lines of weakness **21** imparted to the web **14** can be spaced at a distance equal to about the circumference of the cylinder **12** divided by the number of anvils **16** spaced equidistant to one another. Stated another way, the spacing of lines of weakness **21** on the web **14** can be about equal to the spacing between each anvil **16** disposed on the outer surface **30** of the cylinder **12**. For example, a cylinder **12** comprising nine rows of anvils **16** disposed radially about the outer surface **30** and a desired sheet length of about four inches, the cylinder **12** can have a diameter of about 11.5 inches and a circumference of about 36 inches. In an alternative example embodiment, the distance between one or more anvils **16** disposed about the outer surface **30** can be unequal and, thus, the line of weakness **21** on the web **14** can also spaced at unequal distances one from another, being about equal to the distance between adjacent anvils **16** disposed about the cylinder **12**. One of ordinary skill in the art would understand that for the line of weakness **21** on the web **14** to be equal to the distance between the one or more anvils **16**, the speed of the web **14** would substantially match the rotational speed of the cylinder **12** and the longitudinal cylinder axis **24** would be substantially perpendicular to the machine direction of the web **14**. Likewise, one of ordinary skill in the art would understand that by over-speeding or under-speeding the web **14**, the MD spacing between the lines of weakness **21** can be varied with respect to the spacing between anvils **16** on cylinder **12**. In another embodiment, the cylinder **12** can be both over-sped and under-sped to produce variable sheet lengths in the web **14**. Thus, the cylinder can be run at a constant over-speed, a constant under-speed or variable speeds, both over-speed and under-speed.

The anvil **16** can have any substantially continuous, non-linear shape (also referred to as a curvilinear shape), for example, a sinusoidal shape or saw-tooth shape, as illustrated in FIGS. **1**, **5**, **6**, **7**, and **23**A-Q. The continuous line segment shape of the anvil **16** is dependent on the desired shape of the line of weakness **21** in the web **14**.

As illustrated in FIGS. **5**A-G, the continuous line segment shaped anvil **16** can have a shaped cross section. The anvil **16** can be any non-linear shape that allows the anvil **16** to cooperate in contacting relationship with the blade **20** to impart a line of weakness **21** to a web **14**. In one embodiment, the anvil **16** can have a substantially square or rectangular cross section. In another example embodiment, the anvil **16** can have a substantially flat top, as shown in FIGS. **5**D and **5**E. Similarly, the anvil **16** can have a substantially concave or convex cross section. Still in another embodiment, the anvil **16** can have a substantially triangular cross section. Other cross sections that would allow for the anvil **16** to be in contacting relationship with the blade **20** would be readily discernible to one skilled in the art. Further, the anvil **16** can be designed such that the stresses are minimized at the root **72**. For example, in one embodiment, the root **72** can be radiused with a radius of curvature that minimizes stress concentrations. The radius of curvature can range from 0.010 inches to about 1 inch.

Referring to FIG. **5**, in one embodiment, the anvil **16** can be a continuous line segment shape that is substantially parallel to or at some angle to (discussed more fully below) the longitudinal cylinder axis **24**. The continuous, non-linear shape of the anvil **16** can comprise an amplitude **32**, which is the distance measured between a highest point and an adjacent lowest point, opposite the highest point, of a shaped anvil **16** along the outer surface **30** of the cylinder **12**. The amplitude **32** can vary between adjacent high points and low points. One or more amplitudes **32** present on the outer surface **30** of the cylinder **12** can be substantially the same or different. Similarly, the anvil **16** can comprise a wavelength **34**, which is the distance measured between adjacent crests or adjacent troughs in a repeating portion of the continuous line segment shaped anvil along the outer surface **30** of the cylinder **12**. For example, as shown in FIG. **5**, the anvil **16** repeats at a first low point and a consecutive low point that defines a distance therebetween being the wavelength **34**. In one embodiment, the anvil **16** can comprise less than one repeating portion and, thus, the number of wavelengths **34** would be less than one. In another embodiment, the anvil **16** can comprise more than one wavelength **34**. More specifically, for example, as shown in FIG. **5**, the anvil **16** can comprise about two wavelengths **34** labeled A and B. The distance of wavelength A can be greater than, less than, or equal to the distance of wavelength B.

The wavelength **34** and amplitude **32** can be selected to minimize or avoid chatter in the perforating apparatus **10**. Chatter is the vibration imparted to the perforating apparatus **10** as the blade **20** cooperates in contacting relationship with the anvil **16** at operating speeds. Chatter can be avoided or reduced by minimizing the number of simultaneous interaction points **26** between the anvil **16** and the blade **20**. The continuous line segment shape of the anvil **16** can allow for a reduction in the number of interaction points **26** between the anvil **16** and the blade **20**. For example, in one embodiment, the anvil **16** can comprise a wave-form shape, as shown in FIG. **5**, that is substantially parallel to the longitudinal cylinder axis **24**. The shape of the anvil **16** results in a certain number of interaction points **26** as the straight blade **20** passes over the anvil **16**. For example, as the blade **20** passing over the anvil **20**, as shown in FIG. **5**, the blade **20** overlaps the anvil **16** creating interaction points **26** of at most about five points and at least about two points at a given moment in time. Therefore, changing the amplitude **32** and wavelength **34** of an anvil **16** that is substantially parallel to the longitudinal cylinder axis **24** will change the number of interaction points **26** between the anvil **16** and blade **20** at a given moment in time.

One of ordinary skill in the art would understand that the anvil **16** can be designed to impart a desired shape of a line of weakness **21** in the absorbent tissue product. In one embodiment, the anvil **16** can be designed such that the line of weakness **21** on a web **14**, such as absorbent sheet product (also referred to as a sanitary tissue product), can have a wavelength **34** from about 10% of the sheet width to about

200% of the sheet width and an amplitude **32** of less than about 50% of the distance between adjacent lines of weakness **21**. For example, in one embodiment, the absorbent sheet product can have a width of about 3.5 inches and the distance of the wavelength **34** can be about 50% of the sheet width, which is about 1.75 inches. Thus, the line of weakness **21** imparted to the absorbent sheet product can have at least one wavelength **34**. For example, an absorbent sheet product having a distance between adjacent lines of weakness **21** of about 4 inches can comprise a line of weakness **21** having an amplitude **32** of about 2 inches.

Still further, chatter can be reduced by nesting one or more anvils **16** disposed on the outer surface **30** of the cylinder **12** (not shown). By nesting one or more anvils **16** the blade **20** can remain in constant contact with the anvil **16**. Having the blade **20** in constant engagement with the anvil **16** can allow the cylinder **12** to remain balanced and stabilized and, thus, reduce chatter in the perforating apparatus **10**. Additionally, other ways to reduce chatter include, for example, positioning the anvil **16** so that it is helixed about the cylinder **12**. As illustrated in FIGS. **6** and **7**, the anvil **16** can be mounted at an angle with respect to axis **24**, such that it extends in a helical orientation on the outside surface **30** of the cylinder **12**. The anvil **16** can be at an angle α to the longitudinal cylinder axis **24** of from greater than 0 degrees to about 45 degrees and/or from about 2 degrees to about 20 degrees and/or from about 4 degrees to about 8 degrees. When used with a blade **20** positioned substantially parallel to cylinder axis **24**, the helically mounted anvil **16** can reduce the number of simultaneous interaction points **26** at a given period in time between the anvil **16** and the blade **20**. In one embodiment, the helically mounted shaped anvil **16** results in cooperation between the anvil **16** and blade **20** such that there less simultaneous interaction points **26** than a similar non-helixed anvil **16**.

In one example embodiment, each perforation **22** in the line of weakness **21** can be formed one at a time as the anvil **16** interacts with the straight blade **20** at a single location at a given moment in time. By helically mounting the anvil **16**, the blade **20** operatively engages the anvil **16** at minimal interaction points **26**. For example, the blade **20** can engage the helical anvil **16** such that the perforations **22** are created by a consecutive series of minimized interaction points **26** across the entire web **14** in a zipper-like manner. Further, helically mounting the anvil **16** can allow the anvil **16** to be in constant engagement with the blade **20**. Stated another way, by helically mounting one or more anvils **16** about the outer surface **30** of by the cylinder **12** a portion or point of the anvil **16** can always be in contact with a portion or point of the blade **20**, as illustrated in FIG. **8**. In one embodiment, the blade **20** can have almost traversed one anvil **16** such that substantially the entire line of weakness **21** has been imparted to the web **14** while almost simultaneously encountering a subsequent anvil **16**, such that the creation of the line of weakness **21** in the web **14** is just beginning. Having the blade **20** in constant engagement with the anvil **16** can allow the cylinder **12** to remain balanced and stabilized and, thus, reduce chatter in the perforating apparatus **10**.

However, helically mounting the anvil **16** about the cylinder **12** and running the web **14** at matched speed to the cylinder **12**, can result in the line of weakness **21** being at an angle to the CD, as illustrated in FIG. **8**. The angle of the helixed anvil **16** to the longitudinal cylinder axis **24**, angle α, can be substantially the same angle of the line of weakness **21** to the cross machine direction, CD. To compensate for the angle in the line of weakness **21**, the web **14** can be run at a speed slower than the cylinder **12**. By running the web **14** slower than the rotating cylinder **12**, the web **14** can move a lesser distance before each subsequent perforation **22** is imparted to the web **14**. However, there are limitations as to how fast or how slow the cylinder **12** can be sped with respect to the web **14**.

The perforating apparatus **10** can also be skewed with respect to the web **14** to correct for an angle in the line of weakness **21** with respect to the CD, as shown in FIG. **9**. Thus, the angle of the perforating apparatus **10** with respect to the web **14** allows a line of weakness **21** that is substantially parallel to the CD to be imparted to the web **14** despite the helically mounted anvil **12**. More specifically, as disclosed above, the anvil **16** can be helixed at some angle α with respect to the longitudinal cylinder axis **24**. The cylinder **12** comprising the anvil **16** and the support **18** comprising the blade **20** can be skewed by some angle θ with respect to the CD of the web **14**. The cylinder **12** and the blade **20** are skewed relative to one another such that the longitudinal cylinder axis **24** is substantially parallel to the blade **20**. The angle θ can be equal to about the angle α. The angle θ can be greater than or less than about the angle α. In one example embodiment, the angle θ can be from 0 degrees to about 45 degrees and/or from about 2 degrees to about 20 degrees and/or from about 4 degrees to about 8 degrees.

Where the web **14** is skewed with respect to the perforating apparatus **10**, the web **14** may experience a force vector that drives the web **14** off of a desired path as the web **14** is exiting the perforating apparatus **10**. In other words, the web **14** may travel at an angle out of the perforating apparatus **10** as opposed to following a desirable straight line path **15**. Wrapping the web **14** about one or more idlers may reduce the web **14** likelihood to travel at an undesirable angle. In one nonlimiting example, an idler is placed upstream of the cylinder **12** and/or upstream of blade **20**. In another nonlimiting example, an idler is placed downstream of the cylinder **12** and/or downstream of the blade **20**. The idler may be wrapped with sandpaper, such as 60-grit sandpaper or 120-grit sandpaper. In another embodiment, the idler can be provided with a means to increase the coefficient of friction on its surface.

Further to the above, the characteristics of the line of weakness **21** on the web **14** can be changed by over-speeding or under-speeding the web **14** and/or the cylinder **12** comprising the shaped anvil **16**. As illustrated in FIG. **10**, the shape of the line of weakness **21** on the web **14** can change when over-speeding the web **14** with respect to the rotating cylinder **12**, which is also referred to as under-speeding the rotating cylinder **12** with respect to the speed of the web **12**. When the web **14** moves at a faster speed than the rotating cylinder **12**, the line of weakness **21** can become distorted as compared to the shape of the anvil **16**. For example, a web **14** moving at a faster speed than the cylinder **12** through the interaction point **26** can have an increased amplitude **32** as shown in FIG. **10**R. FIGS. **10**A-**10**R illustrate how perforations **22** can be imparted to a web **14** running at an over-speed. Thus, FIG. **10**A depicts the first interaction point **26** of the anvil **16** to the blade **20** creating a perforation **22**, FIGS. **10**B through **10**Q depict the progression of the web **14** and the perforations **22** imparted to the web **14**, and FIG. **10**R shows the final interaction point **26** of the anvil **16** and the blade **20** creating the final perforation **22** in the web **14**.

One of ordinary skill in the art would understand that by over-speeding the cylinder **12** with respect to the web **14**, the line of weakness **21** would again become distorted as compared to the shape of the anvil **16**. For example, by over-speeding the cylinder **12** with respect to the web **14**, the amplitude **32** of the line of weakness **21** will become shorter than the amplitude of the shaped anvil **16**. Thus, the design of the shaped anvil **16** disposed on the cylinder **12** should be taken into consideration to produce the desired line of weakness **21** when over-speeding or under-speeding the web **14** or the cylinder **12**.

Further, the web **14** can be perforated while under tension in the machine direction MD. The tension on the web **14** in the MD results in the web **14** becoming elongated in the MD and narrower in the cross machine direction CD. This phenomena of elongation in the MD and narrowing in the CD is referred to as neck-down. For a web **14** under tension in the MD and narrowed in the CD as it is passed through the perforating apparatus **10**, the line of weakness **21** imparted to the web **14** on the final rolled absorbent product can be different than the profile of the shaped anvil **16** disposed on the rotating cylinder **12** and/or the shaped line of weakness **21** imparted to the web **14** just after passing through the perforating apparatus **10**. Once the web **14** is wound onto a final rolled absorbent product and is no longer under the same tension as when perforated, the web **14** can return to its original, non-tensioned dimensions. More specifically, the web **14** in the MD can contract back and the web **14** in the CD can become wider. The shaped line of weakness **21** imparted to the web **14** undergoes a similar transformation once the tension in the web **14** is lessened or removed. In one example embodiment, a curvilinear line of weakness **21** on the final rolled absorbent product, which was perforated under tension and is now no longer under tension, can have an amplitude that is less than the amplitude imparted when the web **14** was under tension just after passing through the perforating apparatus **10**, and an increased wavelength distance as compared to the distance of the wavelength of the web **14** under tension after just passing through the perforating apparatus **10**. Thus, the shape of the anvil **16** disposed on the rotating cylinder **12** can be designed to account for the tension, if any, in the web **14** so as to produce the desired curvilinear shape in the line of weakness **21** of the final rolled absorbent product.

In yet another embodiment, the anvil **16** can be smooth-edged or notched, as shown in FIGS. **6** and **11**, respectively. As illustrated in FIGS. **11** and **12**, a notched anvil **16** can comprise a plurality of teeth **36** and one or more recessed portions **38**. Each adjacent tooth can be separated by a recessed portion **38**. The one or more teeth **36** and/or recessed portions **38** can be machined into the anvil **16** or removably attached to the anvil **16**. Referring to FIG. **12**, each tooth **36** can have a length TL and a height TH and each recessed portion **38** can have a length RL. Each recessed portion **38** can be separated by an adjacent tooth length TL. The tooth height TH can be designed to obtain the desired perforation characteristics. In one example embodiment, the tooth height TH can be from about 0.005 inches to about 0.500 inches, including every 0.001 inches therebetween. The tooth length TL is dependent upon the desired size of perforation. Stated another way, the spacing of the one or more teeth **36** and one or more recessed portions **38** determines the spacing of each perforation **22** and bond area **23** along the line of weakness **21**. Thus, the spacing of the one or more notches **36** and one or more recessed portions **38** can be such that evenly spaced perforations **22** are produced in the web **14** despite the shape of the anvil **16**. This will be discussed in greater detail below. Alternatively, the anvil **16** can comprise a smooth-edge or non-notched edge, as shown in FIG. **1**. Generally, if the anvil **16** comprises a plurality of teeth **36**, the blade **20** can comprise a smooth-edge or non-notched edge, as shown in FIG. **11**. Likewise, if the anvil **16** is smooth-edged, that is contains no teeth, the blade **20** can comprise a plurality of teeth **36**.

As discussed above, the support **18**, as shown in FIGS. **1** and **2**, can comprise a support surface **40** and a blade **20** disposed thereon. The support **18** can be formed from metal, such as steel or a steel alloy, or from some other material as would be known to those skilled in the art to be suitable as a structural support of perforating equipment. The support **18** can be in a block shape, as illustrated in FIG. **2**, a cylindrical shape, as illustrated in FIG. **13**, or another shape that would adequately support a blade **20**. The support **18** can be placed in a fixed, non-moveable, non-rotatable position during contacting relationship with the anvil **16**, independent of the shape of the support **18**. In one example embodiment, the support **18** can be a cylindrical shape or a substantially square shape such that when one or more blades **20** disposed on the outer surface wear or break, the support **18** can be rotated and fixed in a position so that a new blade **20** can be placed in contacting relationship with the anvil **16**. Alternatively, the support **18** can be rotated and/or adjusted in and out of contacting relationship with the anvil **16** to easily and readily replace worn or damaged blades **20**.

One or more blades **20** can be disposed around the support surface **40**, as shown in FIGS. **1**, **14**, and **15**. Having more than one blade **20** disposed about the support surface **40** can allow for quick change out of worn or damaged blades by indexing or rotating the support surface such that a new blade engages with the anvil **16**. Additionally, having more than one blade **20** can allow for quickly changing to different blade orientations or configurations leading to different line of weakness **21** characteristics, such as different shapes, and different individual perforations **22** characteristics, such as length, in the web **14**. For example, the width and length of one blade **20** disposed about the support surface **40** can be different than the length of an adjacent blade **20** disposed about the same support surface **40**.

Still referring to FIGS. **14** and **15**, the blade **20** can be removably secured to the support **18**. The blade **20** can be adjusted on the support **18** to be adequately positioned to engage with the anvil **16**. The blade **20** can be positioned substantially parallel to the longitudinal cylinder axis **24**. The blade **20** disposed on the support **18** can be substantially parallel to or substantially perpendicular to a support surface **40**. Alternatively, the blade **20** can be at some angle β to the support surface **40**. The angle β can be from about 20 degrees to about 160 degrees and/or from about 20 degrees to about 110 degrees and/or from about 23 degrees to about 90 degrees and/or about 25 degrees to about 60 degrees, and/or about 20 degrees to about 26 degrees, for each range including every 0.1 degree therebetween. It is believed that the lower the angle β, the higher the degree of flexibility when operating the apparatus **10**. More specifically, the perforating apparatus **10** is less sensitive to changes in the distance between the cylinder **12** and the support surface **40** when the angle β is lower. For instance, where β is 35 degrees, a change in the distance between the support surface **40** and the cylinder **12** by just a couple of thousandths of inches could result in uneven, ripped or otherwise inadequate perforations **22**. On the other hand, where β is 21 degrees, the distance between the support surface **40** and the cylinder **12** can be adjusted by thousandths of inches without perforation **22** quality issues. Indeed, the instance of β being 21 degrees permits an adjustment range (i.e., adjusting the distance between the support surface **40** and the cylinder **12** with perforation **22** quality issues) of about two times, or about three times or about four times more than the adjustment range when β is 35 degrees. Further, the lower the angle β, the less stress applied to the blade **20**.

In one embodiment, the blade **20** can be in a cantilevered position. The cantilevered position can allow for the blade **20** to flex at or near its distal end. More specifically, as the anvil **16** cooperates with the blade **20**, the distal end of the perforating blade flexes against the anvil **16** to create the line of weakness **21** in the web **14**. The blade **20** can be made of tungsten carbide or other suitable material and is commercially available from The Kinetic Company. The blade **20** can be coated with materials to enhance its strength and wear resistance (also referred to as machine life). For example, in one embodiment, the blade **20** can be subject to plasma-enhanced chemical vapor deposition to deposit a thin film of material on the surface of the blade **20**. Materials that can be used to prolong the machine life of the blade **20** can include titanium oxide and ceramic coatings. Generally, the anvil **16** is a substantially hardened surface that does not flex or minimally flexes when in contacting engagement with the blade **20**.

As previously disclosed, the support **18** can be in any orientation with respect to the cylinder **12** that allows the blade **20** and anvil **16** to cooperate in contacting relationship to impart one or more perforations **22** onto the web **14**, as shown in FIG. **15**. Also shown in FIG. **15**, the web **14** progresses in the MD, which is also the direction of rotation of the cylinder **12**. Further, the support **18** can comprise a blade **20** that can be made up of a single-continuous blade or a plurality of blade segments extending in an end-to-end relationship across the length SL of the support **18**, as illustrated in FIGS. **13** and **16** respectively. That is, a support **18** can comprise a plurality of blade segments **20** that abut one another in length-wise fashion to act similar to a continuous blade. Alternatively, the plurality of blade segments **20** can be spaced such that at least one blade **20** is not in contact with an adjacent blade **20**. Still further, the plurality of blade segments **20** can be spaced such that no one blade **20** is in contact with another blade **20** across the length SL of the support **18**.

As illustrated in FIGS. **17** and **18**, the blade **20** can comprise a plurality of teeth **36** and one or more recessed portions **38**. The plurality of teeth **36** and/or recessed portions **38** can be machined into the blade **20**, or one or more blades **20** can be assembled to produce one or more recessed portions **38** and one or more teeth **36**. As previously disclosed, each tooth **36** can have a length TL and a height TH and each recessed portion **38** can have a length RL. Each recessed portion **38** can be separated by an adjacent notch length NL. The tooth height TH can be designed to obtain the desired perforation characteristics. In one embodiment, the tooth height TH can be from about 0.005 inches to about 0.500 inches, including every 0.001 inches therebetween. Further, the spacing of the one or more teeth **36** and one or more recessed portions **38** can relate to the spacing of each perforation **22** and bond area **23** along the line of weakness **21** in the web **14**. Thus, the spacing of the one or more teeth **36** and one or more recessed portions **38** can be such that evenly spaced perforations **22** are produced across the line of weakness **21** in the web **14**. This will be discussed in greater detail below. Alternatively, or in addition to a notched blade **20**, the blade **20** can comprise a smooth-edge, as shown in FIG. **13**. Generally, a notched blade **20** cooperates in contacting relationship with a smooth-edge anvil **16**, as shown in FIG. **18**.

Referring now to FIG. **19**, as can be understood by considering the present disclosure, a blade **20** and/or an anvil **16** can comprise one or more teeth **36** and one or more recessed portions **38** for making a line of weakness **21** comprising one or more perforations **22** and bond areas **23** in the web **14**. In one embodiment, the blade **20** disposed on the support **18** comprises one or more teeth **36** and one or more recessed portions **38**, and the cylinder **12** comprises an anvil **16** in a wave-form shape. Due to the wave-form shape of the anvil **16**, the rotation of the anvil **16** toward the blade **20**, and the length of the one or more teeth **36** and the one or more recessed portions **38**, a certain perforation length PL, as shown in FIGS. **19** and **22**, can be imparted to the web **14**. For example, in one embodiment, the length of the one or more teeth **36** and the one or more recessed portions **38** are uniform in length. The uniform length of the one or more notches **36** and the one or more recessed portions **38** can result in non-uniform perforation lengths PL due to the curvilinear shape of the anvil **16**. By "uniform" is meant that the lengths are substantially equal or within about 15% or less of each other. By "non-uniform" is meant that two or more lengths are not equal or are greater than about 15% of one another.

Therefore, in one embodiment, a perforating apparatus **10** can be designed to make a line of weakness **21** comprising one or more perforations **22** having a substantially uniform perforation length PL. Alternatively, or in addition to uniform perforation lengths PL, the space between each perforation **22**, the bond area **23** can have a non-perforation length NP, where the NP can be substantially uniform. As previously disclosed with respect to FIG. **1**, the perforating apparatus **10** can comprise a cylinder **12** that rotates about a longitudinal cylinder axis **24** and a fixed support **18** between which a web **14** is advanced in the machine direction MD. More specifically, a wave-form shaped anvil **16** disposed on the cylinder **12** rotates and engages in contacting relationship with a straight, notched blade **20** disposed on the fixed support **18**.

Referring to FIG. **19**, the anvil **16** is depicted schematically as a continuous line, but can be any size fit for the cylinder **12** of a perforating apparatus **10**, and can be made up of a plurality of individual anvil segments disposed on the cylinder **12** to form a shaped line of weakness **21** in the web **14**. The wave-form (also referred to as shaped or curvilinear or nonlinear) shape of the anvil **16** can be primarily dependent on the desired shape of the line of weakness **21** in the finished web **14**. The blade is schematically depicted as a straight piece comprising one or more teeth **36** and one or more recessed portions **38** with variable lengths. As stated above, the blade **20** and anvil **16** cooperate in contacting relationship to perforate the web. Still referring to FIG. **19**, each tooth **36** has a length TL and can be separated by a recessed portion **38** that also has a length RL. The hash marks **42** on the anvil **16** indicate the end positions of each tooth **36** based on the tooth length TL. Further, dashed lines **44** connect the hash mark **42** corresponding to each tooth **36** and, more specifically, the end positions of each tooth **36**. If a uniform perforation length PL is desired, the tooth length TL and corresponding recessed length RL must account for the shape of the anvil **16**. As shown in FIG. **19**, the hash marks **42** placed along the anvil **16** can be such that a uniform line of weakness is imparted to the web **14**. However, as shown by following the dashed lines **44** from the blade **20** to the anvil **16**, to achieve uniform perforation lengths PL and/or non-perforated lengths NP, the lengths of the teeth **36** (or recessed portions **38**) must vary along the length of the blade **20**. For example, tooth length TL_1 is longer than TL_2, as shown in FIG. **19**, yet each produce a perforation having substantially the same perforation length

LP along the shaped anvil **16**. Similarly, RL_1 is longer than RL_2, but such spacing or non-perforation portion produce substantially uniform non-perforated lengths NP along the shaped anvil **16**.

Each tooth length TL can be individually predetermined such that its projected contacting relationship onto the anvil **16** delimits a length of the anvil **16** substantially equal to a desired perforation length PL in the web **14**. Each recessed portion length RL is individually predetermined such that its projected relationship with respect to the anvil **16** delimits a length of the anvil **16** substantially equal to a desired bond area having non-perforated length NP in the web **14**. For example, each tooth length TL and recessed portion length RL can be designed such that the lines of weakness **21** in the web **14** comprises perforations **22** that are longer at the edge of the web **14** compared to the perforations toward the middle of the web **14**, or bond areas **23** that are shorter near the edge compared to the bond areas toward the middle of the web **14**.

Referring now to FIGS. **20** and **21**, the tooth length TL and recessed portion length RL for an individual tooth **36** and recessed portion **38** on the blade **20** can be calculated. In one example embodiment, the tooth length TL or the recessed portion length RL can be determined by first measuring or predetermining a desired perforation length PL or non-perforation length NP, as shown between adjacent hash marks **42**. Next, connect adjacent harsh marks **42** with a straight line **46** and intersection the straight line **46** with a line **48** substantially parallel to the outside edge of the blade **20** forming an angle ε. The straight line **46** should intersect the substantially parallel line **48** at a hash mark **42** so that the angle ε is less than about 90 degrees. Assuming that the tooth **36** and/or recessed portion **38** has a surface that is substantially parallel to the outer surface **30** of the cylinder **12**, the trigonometry of a right triangle can be used to calculate the tooth length TL and the recessed length RL. More specifically, still referring to FIG. **20**, the tooth length TL or recessed portion length RL can be calculated as the desired perforation length PL or non-perforation length NP times the cosine of the angle ε. Similarly, if the a certain tooth length TL or recessed portion length RL is known, the perforation length PL or non-perforation length NP can be calculated using the geometry of a right triangle. Thus, the notch length NL and recessed portion length RL can be determined for any adjacent harsh marks **42**. Additionally, one of ordinary skill in the art would understand that if the blade **20** was not parallel to the outer surface **30** of the cylinder **12**, the resulting triangle would not have a right angle and more advance trigonometry such as the law of sines, law of cosines, and law of tangents could be used to determine the angles and lengths.

Further to the above, in one embodiment, the perforating apparatus **10** can comprise a shaped anvil **16**, disposed on the rotating cylinder **12**, comprising a plurality of teeth **36** and one or more recessed portions **38**, and a blade **20** having a substantially smooth edge, not shown. The perforating apparatus **10** imparts a line of weakness **21** onto the web **14**. The line of weakness **21** will have perforations **22** and bond areas **23** that directly correspond to the teeth **36** and recessed portions **38** of the notched, shaped anvil **16**. Stated another way, when the shaped anvil **16** is notched, having one or more recessed portions **38** and one or more teeth **36**, the location of the recessed portions **38** will substantially correspond to the location of bond areas **23** on the line of weakness **21** and the location of the teeth **36** will substantially correspond to the location of the perforations **22** on the line of weakness **21**. Thus, when the shaped anvil **16** is notched, the design of the recessed portions **38** and teeth **36** should be done in a manner to directly reflect the desired characteristics of the line of weakness **21**.

An example embodiment of the web **14** produced by the present disclosure is shown in FIG. **22**. The web **14** can comprise one or more lines of weakness **21**. The line of weakness **21** can be substantially the same or similar to the curvilinear shape as that of the anvil **16**, as was discussed more fully above. The curvilinear line of weakness **21** can comprise a plurality of perforations **22** and bond areas **23** between adjacent perforations **22**. Each of the plurality of perforations **22** has a perforation length PL that can be substantially the same or different with respect to each other perforation length PL across the curvilinear line of weakness **21**. Similarly, between each adjacent perforation **22** can be a bond area **23** having a non-perforation length NP that can be substantially the same or different relative to other and/or adjacent bond areas. Substantially can refer to the degree of similarity between two comparable units, and, more specifically, refers to those comparable units that are within about 15% of one another. Further, the plurality of perforations **22** can protrude through one or more plies of the web **14**.

As previously stated, each of the plurality of perforations has a perforation length and each of the bond areas has a non-perforation length. In one example embodiment at least two of the perforation lengths are substantially equal. In another example embodiment, at least two of the non-perforation lengths are substantially equal. In yet another example embodiment at least two of the non-perforation lengths are substantially unequal and at least two of the perforation lengths are substantially unequal. In still another example embodiment, the curvilinear line of weakness **21** can comprise at least one wavelength **34**, and the one or more perforations **22** and bond areas **23** can be imparted to the web **14** such that the perforation lengths PL near the edge of the web **14** are longer than the perforation lengths PL near the middle of the web **14** and/or the non-perforation lengths NP are shorter near the edge of the web **14** and longer near the middle of the web **14**. Similarly, the perforations **22** and bond area **23** can be imparted to the web **14** such that the perforation lengths PL are substantially the same at the crest and trough of the wavelength **34** and different between the crest and the trough of the wavelength **34**. Further, the perforations **22** and bond area **23** can be imparted to the web **14** such that the non-perforation lengths PL are substantially the same length at the crest and trough of the wavelength **34** and a different length between the crest and the trough of the wavelength **34**.

A curvilinear line of weakness **21** can allow manufacturers to create a product that consumers can more easily and readily interact with. For example, a notched blade **20** or notched anvil **16** can be designed such that a shaped line of weakness **21** can tear more easily than, or at least as easy as, a straight line of weakness **21**. Generally, the ease with which an absorbent sheet product is torn at the line of weakness is directly associated with the tensile strength of the line of weakness. It is known that the lower the perforation tensile strength, the easier the absorbent sheet product will separate at the line of weakness. The following data, shown in Table 1 below, illustrates the difference in the perforation tensile strength required to tear a shaped, also referred to as curvilinear or nonlinear, line of weakness **21** as compared to that of a straight, also referred to as linear, line of weakness across a full sheet of absorbent tissue product.

The data shown in Table 1 was gathered using the Tensile Strength Test Method as outline below. Generally, the data shows that the peak tensile strength for a shaped line of weakness is less than the peak tensile strength for a straight line of weakness. The peak tensile strength is the maximum force reached along the line of weakness upon completely tearing the line of weakness. As evidenced by Table 1 below, generally, the peak tensile strength of a shaped line of weakness is from about 1% to about 40% less than the peak tensile strength of a straight line of weakness imparted to the web **14** under similar manufacturing conditions, such as blade tooth length and recessed portion length. Stated another way, a shaped line of weakness imparted by the apparatus and method of the present disclosure can have a peak tensile strength that is generally at least about one percent and/or at least about 5% and/or at least about 10% and/or at least about 20% less than the peak tensile strength of a straight line of weakness.

Similar to the above, Table 1 also illustrates that the failure TEA (total energy absorbed) is generally less for a shaped line of weakness as compared to a straight line of weakness. The failure TEA is the area under the curve between the point of initial tensioning of the sanitary tissue product to the point at which the shaped line of weakness has failed. The failure point of the shaped line of weakness is designated by the tension falling below 5% of the peak load. As evidenced in Table 1, generally, the failure TEA of the shaped line of weakness is from about 1% to about 50% and/or about from about 1% to about 30% and/or about 1% to about 20% less than the failure TEA of the straight line of weakness.

TABLE 1

Shaped Anvil Amplitude (inches)	Shaped Anvil Wavelength (inches)	Full Sanitary Tissue Product Sheet Line of Weakness Peak Load (grams)	% Difference in Peak Load from Straight Line of Weakness (control)	Full Sanitary Tissue Product Sheet (4") Line of Weakness Failure TEA (g*in/in)	% Difference in Failure TEA from Straight Line of Weakness (control)	Blade Recessed Portion Length (inches)	No. of Recessed Portions per 4.5" Blade	% Bond Area	Blade Tooth Length (inches)
0	0	604	Control	49.0	Control	0.032	38	27%	0.083
0.06	1.35	545	−10%	42.0	−14%	0.032	38	27%	0.083
0.10	1.35	593	−2%	49.3	1%	0.032	38	27%	0.083
0.15	1.35	608	1%	45.7	−7%	0.032	38	27%	0.083
0.17	0.90	551	−9%	39.5	−19%	0.032	38	27%	0.083
0.17	1.35	579	−4%	44.2	−10%	0.032	38	27%	0.083
0.19	1.35	585	−3%	43.1	−12%	0.032	38	27%	0.083
0.22	1.35	611	1%	44.3	−10%	0.032	38	27%	0.083
0.38	1.56	592	−2%	46.5	−5%	0.032	38	27%	0.083
0.56	1.35	484	−20%	32.9	−33%	0.032	38	27%	0.083
0.56	1.94	524	−13%	34.7	−29%	0.032	38	27%	0.083
0	0	688	Control	60.2	Control	0.013	99	29%	0.032
0.06	1.35	456	−34%	30.4	−49%	0.013	99	29%	0.032
0.10	1.35	716	4%	76.5	27%	0.013	99	29%	0.032
0.15	1.35	609	−11%	52.0	−14%	0.013	99	29%	0.032
0.17	0.90	516	−25%	39.2	−35%	0.013	99	29%	0.032
0.17	1.35	588	−15%	53.7	−11%	0.013	99	29%	0.032
0.19	1.35	557	−19%	41.7	−31%	0.013	99	29%	0.032
0.22	1.35	561	−18%	47.7	−21%	0.013	99	29%	0.032
0.38	1.56	599	−13%	56.0	−7%	0.013	99	29%	0.032
0.56	1.35	428	−38%	28.4	−53%	0.013	99	29%	0.032
0.56	1.94	492	−29%	37.0	−38%	0.013	99	29%	0.032
0	0	462	Control	30.3	Control	0.026	33	19%	0.106
0.06	1.35	433	−6%	27.9	−8%	0.026	33	19%	0.106
0.1	1.35	557	21%	51.7	71%	0.026	33	19%	0.106
0.15	1.35	456	−1%	27.9	−8%	0.026	33	19%	0.106
0.17	0.9045	424	−8%	25.7	−15%	0.026	33	19%	0.106
0.17	1.35	452	−2%	28.6	−6%	0.026	33	19%	0.106
0.1875	1.35	404	−12%	22.1	−27%	0.026	33	19%	0.106
0.22	1.35	476	3%	30.6	1%	0.026	33	19%	0.106
0.375	1.5625	476	3%	45.9	52%	0.026	33	19%	0.106
0.5625	1.35	377	−18%	21.1	−30%	0.026	33	19%	0.106
0.5625	1.94	419	−9%	26.7	−12%	0.026	33	19%	0.106
0	0	810	Control	86.8	Control	0.041	40	37%	0.069
0.06	1.35	668	−18%	73.2	−16%	0.041	40	37%	0.069
0.1	1.35	814	1%	89.1	3%	0.041	40	37%	0.069
0.15	1.35	794	−2%	83.9	−3%	0.041	40	37%	0.069
0.17	0.9045	751	−7%	77.3	−11%	0.041	40	37%	0.069
0.17	1.35	785	−3%	79.3	−9%	0.041	40	37%	0.069
0.1875	1.35	840	4%	87.5	1%	0.041	40	37%	0.069
0.22	1.35	771	−5%	79.6	−8%	0.041	40	37%	0.069
0.375	1.5625	778	−4%	81.6	−6%	0.041	40	37%	0.069
0.5625	1.35	667	−18%	57.7	−34%	0.041	40	37%	0.069
0.5625	1.94	709	−13%	64.4	−26%	0.041	40	37%	0.069

Further, a shaped line of weakness **21** on a sanitary tissue paper product, for example, allows consumers to more easily grasp and dispense the exposed sheet of the product due to the shaped line of weakness **21** creating a series of tabs or a visually identifiable edge. Still further, the shaped line of weakness **21** can allow consumers to readily distinguish a product from other manufacturer's products by having a visually distinctive perforation, such as one that complements an emboss or print pattern. FIGS. **23** A-Q illustrate various shapes of the curvilinear line of weakness **21** that can be imparted to the web. One of ordinary skill in the art based on the aforementioned disclosure would understand that the shape of the line of weakness **21** is due in part to the shape of the shaped anvil **16** or shaped blade **20** disposed on the rotating cylinder **12**. Thus, the shapes shown in FIGS. **23**A-Q could also be the profiles of the shaped anvil **16** or shaped blade **20** disposed on the rotating cylinder **12**. Generally, the profiles depicted in FIGS. **23** A-Q can be described as exhibiting a sinusoidal shape, as being a group of two or more linear elements each connecting at a single inflection point with an adjacent linear element, or a combination of curvilinear and linear elements.

In another example embodiment, the cylinder **12** can comprise a shaped blade **20** and the support **18** can comprise a straight, linear anvil **16**, not shown. Likewise, in another example embodiment, the cylinder **12** can comprise a shaped blade **20** and the support **18** can comprise a straight, linear blade. The above description applies to either of the recited configurations.

Tensile Strength Test Method

Elongation, Tensile Strength, TEA and Tangent Modulus are measured by or calculated from data generated by a constant rate of extension tensile tester with computer interface (a suitable instrument is the EJA Vantage from the Thwing-Albert Instrument Co. Wet Berlin, N.J.) using a load cell for which the forces measured are within 10% to 90% of the limit of the load cell. Both the movable (upper) and stationary (lower) pneumatic jaws are fitted with smooth stainless steel faced grips, with a design suitable for testing the full width of one sheet material. For example, the Thwing-Albert item #734K grips are suitable for testing a sheet having about a four inch width. An air pressure of about 60 psi is supplied to the jaws.

Unless otherwise specified, all tests described herein, including those described in the detailed description, are conducted on samples that have been conditioned in a conditioned room at a temperature of 73° F.±2° F. (23° C.±1° C.) and a relative humidity of 50% (±2%) for 2 hours prior to the test. All tests are conducted in such conditioned room(s). All plastic and paper board packaging materials must be carefully removed from the paper samples prior to testing. If the sample is in roll form, remove at least the leading five sheets by unwinding and tearing off via the closest line of weakness, and discard before testing the sample. Do not test sheet samples with defects such as perforation skips, wrinkles, tears, incomplete perforations, holes, etc.

A full finished product width sheet sample of a paper towel or bath tissue product is cut so that a perforation line passes across the sheet parallel to each cut in the width dimension. More specifically, take two adjacent sheets separated by a line of weakness (comprising one or more perforations), and cut a test sample to include at least a portion of the two tissue sheets. The cuts should be made across the width of the sheet generally parallel to the line of perforation and equally about the line of perforation. For example, the first cut is made at least two inches above the line of weakness comprising perforations and another cut is made on the other side of the line of weakness at least two inches from the line of weakness comprising perforations. At all times the sample should be handled in such a manner that perforations are not damaged or weakened. The prepared sample is placed in the grips so that no part of the line of weakness is touching or inside the clamped grip faces. Further, the line of weakness should be generally parallel to the grip. Stated another way, if an imaginary line were drawn across the width of the sheet connecting the two points at which the line of weakness crosses the edge of the sheet, the imaginary line should be generally parallel to the longitudinal axis of the grips (i.e., perpendicular to the direction of elongation).

Program the tensile tester to perform an extension test, collecting force and extension data at an acquisition rate of 20 Hz as the crosshead raises at a rate of 4.00 in/min (10.16 cm/min) until the specimen breaks (i.e., when the test specimen is physically separated into two parts). The break sensitivity is set to 98%, i.e., the test is terminated when the measured force drops to ≤2% of the maximum peak force, after which the crosshead is returned to its original position.

Set the gage length to 2.0 inches. Zero the crosshead position and load cell. Insert the sheet sample into the upper and lower open grips such that at least 0.5 inches of sheet length is contained each grip. Verify sheet sample is properly aligned, as previously discussed, and then close lower and upper grips. The sheet sample should be under enough tension to eliminate any slack, but less than 5 g of force measured on the load cell. Start the tensile tester and data collection.

The location of failure (break) should be the line of weakness. Each sample sheet should break completely at the line of weakness. The peak force to tear the line of weakness is reported in grams. If the location of the failure (break) is not the line of weakness, disregard the data and repeat the test with another sheet sample. Note, the output result is for the entire sheet sample and therefore does not need to be normalized.

Adjusted Gage Length is calculated as the extension measured at 5 g of force (in) added to the original gage length (in).

Peak Tensile is calculated as the force at the maximum or peak force. The result is reported in units of g/in, to the nearest 1 g/in. Note the output results are for the entire sheet sample width and is not normalized.

Failure Total Energy Absorption (Fail_TEA) is calculated as the area under the force curve integrated from zero extension to the extension at the "failure" point (g*in), divided by the adjusted Gage Length (in). The failure point is defined here as the extension when the tension force falls to 5% of the maximum peak force. This is reported with units of g*in/in to the nearest 1 g*in/in. Again, note that the output results are for the entire sheet sample width.

Repeat the above mentioned steps for each sample sheet. Four sample sheets should be tested and the results from those four tests should be averaged to determine a reportable data point. The data generated in Table 1 above represents data points of an average of four measures generated by the above test method.

The dimensions and values disclosed herein are not to be understood as being strictly limited to the exact numerical values recited. Instead, unless otherwise specified, each such dimension is intended to mean both the recited value and a functionally equivalent range surrounding that value. For example, a dimension disclosed as "40 mm" is intended to mean "about 40 mm."

Every document cited herein, including any cross referenced or related patent or application, is hereby incorporated herein by reference in its entirety unless expressly excluded or otherwise limited. The citation of any document is not an admission that it is prior art with respect to this disclosure or that claimed herein or that it alone, or in any combination with any other reference or references, teaches, suggests, or discloses any such invention. Further, to the extent that any meaning or definition of a term in this document conflicts with any meaning or definition of the same term in a document incorporated by reference, the meaning or definition assigned to that term in this document shall govern.

While particular embodiments of the present disclosure have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the disclosure. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this disclosure.

What is claimed is:

1. A web comprising:

a curvilinear line of weakness comprising at least two wavelengths, the curvilinear line of weakness comprising a plurality of perforations, wherein each of the plurality of perforations is separated by a bond area, and

wherein each of the plurality of perforations has a perforation length and each bond area has a non-perforation length,

wherein at least two of the non-perforation lengths are substantially unequal and at least two of the perforation lengths are substantially unequal, the curvilinear line of weakness has a perforation tensile strength of from about 1% to about 40% less than the perforation tensile strength of a straight line of weakness imparted to the web, as measured according to the Tensile Strength Test Method,

wherein each of the wavelengths comprises a crest and a trough, and

wherein the perforation lengths are substantially the same length at the crests and the troughs of the wavelengths and a different length between the crests and the troughs of the wavelengths, and

wherein the non-perforation lengths are substantially the same length at the crests and the troughs of the wavelengths and a different length between the crests and the troughs of the wavelengths.

2. The web of claim **1**,

wherein the curvilinear line of weakness has a failure total energy absorbed (TEA) of about 1% to about 50% less than the failure TEA of a straight line of weaknes.

3. The web of claim **1**, wherein the curvilinear line of weakness has a failure total energy absorbed (TEA) of at least about 5% less than the failure TEA of a straight line of weakness.

4. The web of claim **1**, wherein the web has a width of about 3.5 inches, and the distance of each of the wavelengths between adjacent crests or adjacent troughs of the wavelengths is about 50% of the width.

5. The web of claim **1**, wherein the wavelengths have an amplitude of about 2 inches.

6. The web of claim **1**,

wherein the web has multiple curvilinear lines of weakness and the wavelengths of each curvilinear line of weakness have an amplitude of less than about 50% of the distance between adjacent curvilinear lines of weakness.

7. The web of claim **1**, wherein the perforation lengths are between 0.032 inches and 0.106 inches.

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